NUCLEAR ENGINEERING VOL. 4 NO. 40 JULY — SEPT., 1959

A Damp Summer

THE popular pastime in the United Kingdom this year appears to be pouring cold water on prospects in the atomic energy field and not apparently for the purposes of irrigation. Although not as violent a reaction as the reappraisal in America two years ago the tendency latterly has been to point the problems, the dangers and the pit-falls rather than the exciting prospects and the solid promise that has been the pattern heretofore. This pessimism is not universally expressed, but rumblings are to be heard from many quarters and have reached a new peak with the awarding of the Trawsfynydd contract to Atomic Power Constructions. This group reckoned by the big four to be something of an outsider has now established itself as a firm contender for future contracts and the original groups can now expect on average only 20% of the total business as against 25%.

One disappointment has been the export market which has proved narrower and more difficult than was originally anticipated; it is not, however, non-existent. N.P.P.C. is currently constructing the world's first export power reactor at Latina, G.E.C. is beginning in Japan, and before the end of the year a British company is likely to be associated with a second European gas-cooled project. An average of one overseas contract a year should be maintained until the first home reactors operate and the position should then improve.

The chief concern is over the home market where the bulk of the business will, at least for the time being, be concentrated. Instead of the 19 stations originally envisaged in the '56-'65 programme the number is likely to be reduced to 10 and over a period one year longer. The total installed capacity will also probably be much nearer the minimum 5,000 MW than was at one time hoped whilst the size of station is double that originally anticipated. Fewer contracts of greater size involve greater expense in the production of tenders and prevent the smooth progression from one job to the next. Although tendering is expensive there is every reason to suppose that a subsequent tender after the first will be less costly and although individual site characteristics inevitably require specialized attention, considerable standardizing of both plant and procedure is possible.

Somewhat similar problems are also posed by the development work involved in a particular design, but the bulk of this development would have been necessary, regardless of the ultimate size of the station and only a small fraction of the work involved in the development of a system is peculiar to a specific site and is not applicable both to other sites and other engineering fields.

Inefficiency in Research

It is true that there is certain duplication and indeed multiplication of research effort but at least in the initial stages this would appear to be inevitable. When the Generating Board is in a position to assume a more dominant role and when measures of effective collaborative research have been developed unnecessary duplication can be avoided. Some is essential, partly to confirm results obtained by other people, partly to try alternative solutions to a given problem. The value of the present collaborative research as practised by the Joint Collaborative Committee must be questioned. The four groups contributing at one stage were convinced that without access to its results the fifth group would carry a heavy handicap in its design work, but the results of the Trawsfynydd contract confound this philosophy. There is little doubt that collaborative research can be useful and can save effort and no doubt a satisfactory method of achieving this will evolve.

Certain of the industries heavily committed in the nuclear engineering field have also had a considerable back log of development and research to undertake. Initial expenditure is inevitably high, but a great deal of research would have been necessary to furnish data for traditional lines of business which are now able to draw upon the experience and information derived specifically for the nuclear engineering field. Indeed, one of the great contributions of nuclear energy to general engineering in this country has been the introduction of a more scientific approach to conventional engineering problems. This is a contribution that is difficult to show on the balance sheet but is none the less material and has contributed significantly to the continued prosperity of these engineering organizations.

It is as well to remember, too, that the increased size of station that is producing problems is a result of inter-group competition and natural evolution and is not the result of misrepresentation by the AEA of probable optimum sizes or changes in attitude by the

generating boards. Such competition is engendered by an appreciation of the ultimate gains to be made by a successful beginning and although in the struggle for power someone is likely to get hurt the ultimate rewards for the successful are proportionately attractive. The squeeze may have appeared uncomfortably early, but the squeeze would have come eventually as it has in all large-scale enterprises; only the strongest, the long-term investors and the successful continue to succeed.

This then, is the background to the agreement worked out between A.E.I.-J.T. and N.P.P.C. to submit joint tenders for Dungeness and Sizewell, leading to full collaboration between the two groups. Extensive reorganization within the concerns will be necessary.

Losses on First Stations

Comments about losses on the construction of the first stations require critical examination before being accepted on their face value. There is a temptation when a number of companies group together to put in a single tender, that profits are extracted both in the supply of the components and also in the supply of the whole. The comment that a group may lose money on a particular contract may be valid as regards the group's finances and the overall costing of the station, but it should not be inferred necessarily that the individual companies in those groups are also to make losses. The manipulation of funds for the construction of such large undertakings is complex and allocations within a given group are as influenced by such outside considerations as income tax as they are by the work in hand. Whilst tender prices continue to decrease, one can only assume either that the loss on the first station is of no great consequence or alternatively that the anticipated ultimate profits are considerable.

There have been some group losses of course on the first stations as a result of inexperience not only because this is a new field of endeavour but also in the straightforward handling of very large single contracts dominated at least initially by the civil engineering. It is relatively unusual for the electrical engineer to be the prime contractor and for the civil engineer to be the sub-contractor. This inversion of position has resulted in needless losses in some instances and some serious miscalculations. In effect, experience is being bought the hard way but when initiating new enterprises this is usually the case, and either this ground training must be endured, or alternatively the responsibility for the major contract must be handled by another organization, traditionally equipped to handle it.

Industrial Vitality

In sharp contrast to the verbal picture of gloom is the continued vitality and prosperity of the groups concerned. English Electric have recently opened their new research laboratories at Whetstone and expanded their interests to include the organic-moderated reactor following a tie-up with Atomics International. G.E.C. are now enthusiastic about their compact enriched design and although the system as submitted to the Galbraith Committee may not be acceptable for ship propulsion, the heat transfer innovations are of great interest in the development of low capital cost central stations. A.E.I. have recently commissioned their research reactor at Aldermaston and through a linkup with General Electric of America are becoming more and more interested in the boiling water systems. N.P.P.C. is not resting content with the AGIP agreement but are expanding their activities in Europe and A.P.C. are in the confident state of having recently received their first contract. Indeed the drive and enthusiasm emanating from the groups is, if anything, gathering momentum rather than abating. Outside the consortia commitments of major companies such as Vickers Nuclear Engineering are steadily increasing and the volume of business in the national research, development and weapons programme must not be underestimated.

No doubt it is deemed politic at this time to plead poverty and to emphasize the difficulties. No doubt it is felt necessary to emphasize the risks inherent in big nuclear engineering developments and to point the large financial losses that might be incurred, on the basis that this will tend to keep outsiders out, and will encourage the generating authorities and the Government to increase the programme.

Dangers of Loose Comment

Too much talk, however, can lead to the opposite effect and can result in depressing nuclear power station construction not only in this country but throughout the world. The temporarily changed state of the coal industry and the mounting coal reserves are somewhat naturally causing a rethinking of the scale on which nuclear power station construction should continue over the next few years. To date the Government has been quite firm in its determination to complete the 5,000 MW programme by 1966 and provided capital costs can continue to come down there is every reason to suppose that nuclear energy can take over more and more of the peak demand after that date. But, if the arguments in favour of nuclear construction become centred around the theme that we require an expanded programme simply to support industry then as the hollowness of this theme becomes obvious the danger of reversion to a fossil firing policy becomes greater. The fundamental arguments in favour of nuclear generation are quite clear. In brief, nuclear construction offers cheaper electricity (and whether the break-even point is 1968 or 1972 is largely of academic interest only and insignificant as far as the consumer is concerned); coal is a primary raw material which should be conserved where possible; too great a dependence on oil is strategically unsound; and of mounting significance is the hazard of air pollution inevitable in fossil firing.

The lower cost can, however, only be achieved by construction and by experience and by building up a healthy nuclear industry. The industry has a right to expect long-term guidance and a solid and regular construction schedule. But, the basic aim is ultimate lower cost, not the meaningless goal of the " maintenance of Britain's lead in this field "—one of the justifications of the Minister of Power for the choice of the Dungeness site.

DIGEST...

Surveying Significant News

Sir Roger Makins to Succeed Lord Plowden

The appointment of Sir Roger Makins to succeed Lord Plowden as AEA's chairman at the year end has raised comment in some quarters that this was properly a post for a technically trained man. Such a view is open to question as the work calls for great administrative ability. Sir Roger brings with him from the Treasury a considerable reputation and the general approval voiced throughout the ranks of the AEA augurs well for his term in office and assures him of a loyal team.

Sir John stays on as Part-time Member

Although, on July 1, Sir John Cockcroft relinquished his post as Member for Scientific Research to take up the Mastership of Churchill College, his place being taken by Sir William Penney, he will remain as a part-time member for the Authority. As leader of Britain's war effort in Canada, then as director of AERE, Harwell, and later Member for Research, Sir John has exerted unparalleled influence on atomic energy developments in this country. It is particularly important that his experience and his counsel will still be officially available.

AEA's Fifth Annual Report

The AEA's report for April 1, 1958, to March 31, 1959 (p. 304), which contains a factual summary of the year's work and a brief review of the past five years' achievements, gives little insight into the Authority's forward thinking. Large stations and gas cooling remain the central themes of reactor concepts but more attention is being given to smaller and mobile plant and to water and organic moderation. The more exotic schemes such as the HAR and LMFR are virtually dead. The Press conference held to answer questions concerning the report was remarkable in that for the first time no reference to fall-out was made, indicating some decay in the strength of the strontium bogy.

A.E.I.-J.T. and N.P.P.C. Amalgamate?

A few weeks after the award of the Trawsfynydd contract to Atomic Power Constructions, A.E.I.-John Thompson Nuclear Energy Co. and the Nuclear Power Plant Co. have announced that in future the two groups would collaborate in nuclear engineering matters. At present, A.E.I.-J.T. is building Berkeley power station and operating MERLIN while N.P.P.C. is building the Bradwell and Latina stations. A joint tender will be submitted for Dungeness and again for Sizewell. Details of the financial terms of integration are still being discussed.

First U.S.-Euratom R. and D. Contracts Placed

The first practical implementation of the U.S.-Euratom research agreement is foreshadowed in an announcement by the Joint Research and Development Board of the placing of three research contracts. Totalling approximately $315,000, the contracts are the first to be awarded from among more than 200 proposals received from U.S. and European firms in response to an invitation issued last December. Two of the contracts go to American concerns—American Standard Corporation, for clad ceramic plate fuel elements by spray-coating techniques, and the Battelle Memorial Institute for boiling-heat-transfer and void distribution studies with water coolants. The third is to a French firm, Compagnie Industrielle des Céramiques Electroniques, for a study project on the extrusion of uranium oxide.

At Least Five Designs for U.S.-Euratom Power Programme

Although the deadline for definite proposals for power projects under the U.S.-Euratom agreement has been postponed from September 1 to October 20, at least five concerns have already expressed their intention to submit projects. The five are: Centre et Sud (Belgium) in conjunction with Electricité de France (France); SEP (Holland); SENN (Italy); and two from West Germany, AKS and Bewag. The first part of the programme calls for 1,000 MW to be installed in the six member countries by the end of 1963.

British Consortia Link-ups with Overseas Concerns

News has been received in the past few months of two important commercial tie-ups of British consortia. G.E.C. has announced that a 10-year agreement has been reached with the German concern MAN who, in exchange for technical information and access to patents, will pay a capital sum together with a royalty on any capacity installed, based on British technology. English Electric's agreement with Atomics International of America provides for training of E.E. staff at Canoga Park and the reactor sites for a nominal sum. The first reactor unit ordered from English Electric would then include E.E.'s conventional equipment but an American reactor; subsequent contracts would require re-negotiation. Once the British side has been brought up to date with organic technology research will be the subject of complete interchange between the two concerns. This agreement is likely to have far-reaching implications, particularly on the marine side.

Clean Boilers

The decision of International Combustion to construct a new factory for manufacturing boilers under clean conditions (p. 294) provides a concrete example of the influence of nuclear engineering techniques upon conventional engineering practice. Equipment is installed which will allow routine production of conventional items of plant under clean conditions rarely approached in heavy engineering work. As a result a better product should be forthcoming and by streamlining methods of inspection and minimizing cleaning and descaling operations reductions in cost should ensue.

BWRA Research Deserves Greater Attention

Research at the British Welding Research Association's Laboratories continues to draw attention to the inadequacy of present codes of practice to cover the manufacture of large pressure vessels of thick plate containing a number of branch pipes. Traditional methods of compensation are expensive and of limited value only; there would appear to be a strong case for reconsidering the permitted design stresses that are at present laid down. A considerable problem arises, however, in translating results of research into working codes and there would seem to be some constrictions in the lines of communication with such bodies as the AEA and the Generating Board. Greater co-operation on this matter could assist considerably in simplifying the design of large pressure vessels and also in bringing down the cost.

Close Timing of Next Two Tenders

Now that the contract for the fifth nuclear station has been settled, the consortia's design teams are concentrating on the next station, Dungeness. Tenders are due by March, 1960, and present indications are that Dungeness will be a 550 MW station. Difficult site conditions will adversely affect the initial cost. Tenders for Sizewell are due in September, 1960, so that the evaluators at CEGB will have a busy year unless some prior limit is placed on the number which can be considered.

Canada's Programme Reviewed

AECL's annual report for the year ending March 31, 1959 is now available; outlining the present programme, the arguments for heavy water moderation are repeated. Experience in operating the 200 MW(t) D_2O-moderated and cooled, tank-type natural uranium fuelled, materials testing reactor in which the coolant at near atmospheric pressure is maintained at a maximum temperature of 75°C is reviewed. A load factor of 97.8% at full power (excluding planned shut-downs) was achieved in the first quarter of 1959. Extruded elements have been developed for this reactor and a complete change to 19-rod clusters is under examination.

The Printing Dispute

Nuclear Engineering regrets the inconvenience caused to readers by the temporary break in publishing brought about by the printing dispute. The current issue has been entitled July-August-September and contains summaries from the emergency news sheets which were distributed to subscribers during the break. Current subscriptions will be extended to compensate for the two issues which were not distributed and the present annual subscriptions will, therefore, cover the January and February issues of 1960. Volume V will be numbered from January, 1960.

Reactor Briefs

MERLIN, A.E.I.-John Thompson's 1-S MW swimming pool research reactor diverged on July 16. . . . At Marcoule, G3 went critical on June 8. . . . Westinghouse's latest testing reactor, WTR, critical on June 30. . . . TRITON, swimming pool research reactor at Fontenay-aux-Roses critical on July 7. . . . Siemens Argonaut-type reactor at Garching near Munich critical on June 23.

Work began on the site on July 1 and this photograph shows some of the heavy plant which Nuclear Civil Constructors will be using.

A.P.C.'s Design for Trawsfynydd

Atomic Power Constructions to build 500 MW nuclear power station in N. Wales

IN response to the CEGB's call for tenders for a 400-500 MW nuclear power station to be built at Trawsfynydd, North Wales, four proposals were received. Of the five British consortia English Electric alone had signified that they were not prepared to tender. On June 10, after several had been critically examined, a letter of intent was sent to Atomic Power Constructions. No official statement has been made of the contract price, but *Nuclear Engineering* understands that the 500 MW station will be built at a cost only 2 or 3% in excess of £100 per kW.

Although the reactors are essentially based on the Calder Hall design, and in general terms are similar to the stations being built by the other consortia, a great deal of improvement has been made in the year that has elapsed since the awarding of the Hinkley Point contract.

It would be trite to suggest that A.P.C.'s success is solely due to careful preparation of their proposal. In point of fact, there are several distinct differences, the most obvious of which concerns the volume rating. Although the output of the station is to be the same as at Hinkley Point, the internal diameter of the reactor pressure vessel is 5 ft 6 in. smaller. This has been achieved by upgrading the operating pressure to 240 p.s.i.g.—which is now almost 2½ times that at Calder Hall. A.P.C. have avoided the complication of variable speed drives for the CO_2 blowers. Their drive is by a constant speed motor, variation in throughput being achieved simply by recirculating any excess through the lower stages of the boiler. This arrangement has the dual advantage of reducing first cost and improving reliability.

Low Efficiencies Attacked

A.P.C. have also attacked low efficiencies in the turbine hall. Full details of their accomplishment have not been divulged but it would appear that the company has evolved a dual pressure turbine design which utilizes steam conditions with a high degree of moisture in the exhaust stage. This is presumably made possible by the introduction of drying facilities, an established method of improving turbine efficiency in theory, but very difficult to execute in practice. It is understood that this innovation was made after long consultations with the Generating Board and could well herald a revolutionary change in turbine practice in this country should it prove as successful as is at present expected.

Pressure Vessels

The reactor pressure vessels, each 61 ft i.d. are fabricated from 3½ in. plate. The graphite moderator is 48 ft across flats and 27 ft 6 in. high with 3,720 vertical fuel channels on a square lattice pitch of 7¼ in. There is a circumferential gas seal between the graphite and moderator structure. The six boilers associated with each reactor are placed in line in two groups of three, on opposite sides of the pressure vessel. The boiler shells are 18 ft i.d. and 116 ft high and are fabricated from 2½-in. steel boiler plate. A dual pressure steam cycle has been adopted, the boilers generating 65% of the steam at high pressure. Each boiler shell contains six sets of tube banks, namely: mixed economizer, L.P. evaporator, H.P. economizer, H.P. evaporator, L.P. superheater and H.P. superheater. All tubes throughout the boiler have external fins, in order to improve the heat transfer between the gas and the steam. One gas circulator is connected to each boiler and is located vertically below the boiler. Each circulator is a single-stage, axial-flow fan, designed to return the CO_2 to the reactor. The power consumed by each circulator is about 6,000 h.p. A feature of the station is the constant speed circulator drive which consists of an induction motor running at 2,950 r.p.m. directly coupled to the circulators. During operation the gas flow is regulated by linked throttle valves in the main gas ducts and by-pass valves in recirculation ducts.

The charge machines are designed to handle fuel whilst the reactor is on load. Each machine is a composite unit capable of carrying out all operations connected with the fuel handling system on the charge face. The machines are approximately 64 ft high and weigh approximately 380 tons each. Remote and local control are provided for charge machine operations but normal operation will be from a remote control room near the charge face.

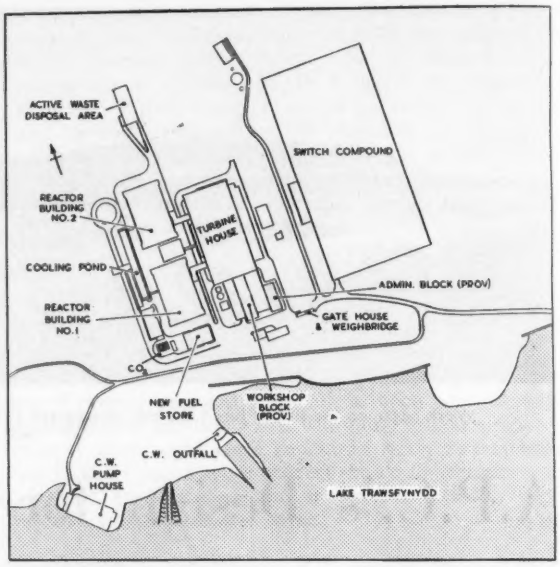
The control of the station during normal operation is carried out from a central room which is situated between the two reactor buildings. There are two automatic control

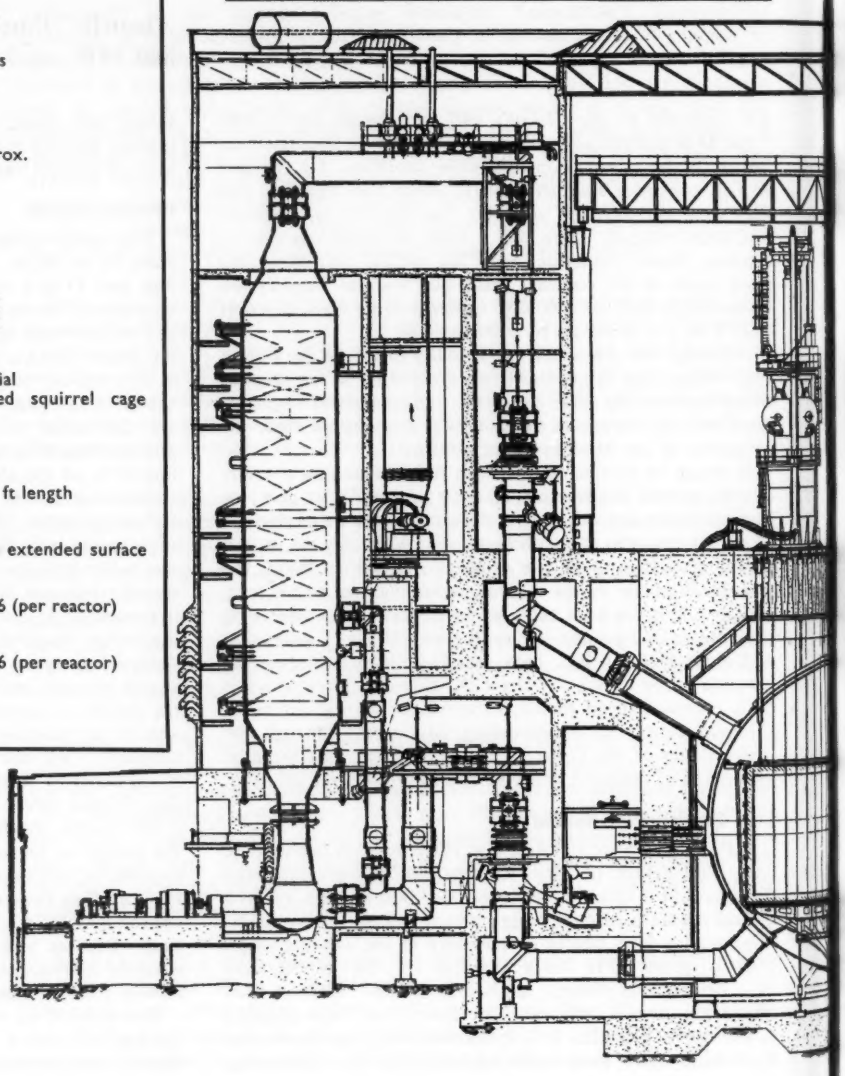
loops external to the reactor; one is primarily intended to eliminate instabilities in the reactor neutron flux, the other is used for adjusting the reactor output to meet the load demand. Provision is made for full automatic control of the station if required.

The turbo-generators are arranged transversely in a turbine house 450 ft long and 220 ft wide. Each generator has a maximum continuous rating of 145 MW and is a four-cylinder machine designed for a dual pressure steam cycle. The steam is discharged from each turbine through six exhausts into twin condensers. The generators have water-cooled stator windings.

Design Parameters

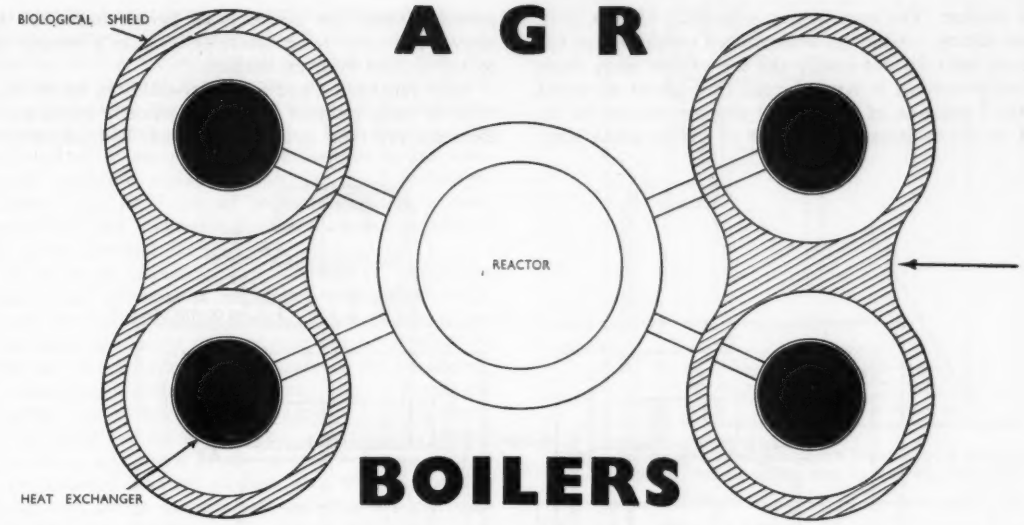
Operator	CEGB
Designer	APC
Prime purpose	Power
No. of reactors	2
Installed capacity	580 MW (+1×145 MW?)
Guaranteed output	500 MW
Reactor output (H)	Approx 870 MW×2
Fuel	Natural uranium
Charge	Approx. 280 tons
U rod dia.	1⅛ in.
Cladding	Magnox
Max. can temp.	Approx. 440°C
Graphite height	27 ft 6 in.
Graphite dia.	48 ft across flats
No. of fuel channels	3,720
No. elements/channel	9
Lattice pitch	7.75 in.
Moderator	Graphite
Wt. of graphite	1,900 tons approx.
Control rod material	Boron steel
P.V. shape	Spherical
P.V. diameter	61 ft
P.V. plate	JT 101
Plate thickness	3½ in.
Operating pressure	240 p.s.i.g.
Coolant	CO_2
Inlet temp.	Approx. 200°C
Outlet temp.	Approx. 400°C
Mass flow	9,000 lb/sec
Duct dia.	5 ft 6 in.
Circulators	Single stage axial
Drive	Constant speed squirrel cage motors
Blower power	6,000 h.p.
No. of boilers	6
Type	Shell and tube
Dimensions	18 ft dia.×116 ft length
Shell material	Boiler plate
Shell thickness	2½ in.
Tubing	Tube Products extended surface
H.P. steam temp.	715°F
H.P. pressure	927 p.s.i.g.
H.P. flow	290,000 lb/h×6 (per reactor)
L.P. temp.	685°F
L.P. pressure	290 p.s.i.g.
L.P. flow	155,000 lb/h×6 (per reactor)
Feed temp.	220°F
Thermal shield	None
Biological shield	Concrete





(Above, right) Site layout of the Trawsfynydd station in N. Wales.

(Right) Half-section through one of the two reactors proposed for Trawsfynydd by Atomic Power Constructions.



AGR BOILERS

Higher gas temperatures in reactors require a new approach to the techniques employed in heat exchanger construction. The heat exchangers discussed in the following two articles are being constructed for the Advanced Gas-Cooled Reactor at Windscale by International Combustion Ltd. to specifications evolved by U.K.AEA. The first article deals with the design and assembly of the exchangers and the second with the special provisions made in manufacturing the component parts.

By E. F. P. BENNETT, B.Sc.
Director, International Combustion (Nuclear Applications) Ltd.

General Conception

THE heat exchangers which International Combustion, Ltd., are manufacturing for the Advanced Gas-Cooled Reactor at Windscale show some deviations from the general pattern made familiar by Calder Hall and the current CEGB stations. These alterations mainly arise from the need to accommodate considerably higher gas temperatures and the natural desire to avoid employing—as far as possible—expensive alloy steels.

In their general conception of the design, the Industrial Group of the U.K.AEA adopted two main principles:—

1. The outer walls of the pressure vessels and ducts are swept only by the cooled gases.
2. The inner walls and ducts swept by the hot gases have to withstand only the differential pressure and they are internally insulated, and externally cooled by the return gases.

Four exchangers are being provided each approximately 11 ft diameter by 60 ft high, the main plate thickness of the barrels being $1\frac{7}{16}$ in. The shells are disposed in pairs on opposite sides of the reactor and are supported on six feet which rest on ball bearings to permit freedom of movement for thermal expansion not only of the heat exchanger shells, but also of the rigid ducts connecting the exchangers to the reactor pressure vessel. Each exchanger is in a cylindrical biological shield of concrete, the reactor and all four exchangers being housed in a steel secondary containment vessel.

The hot gas enters the exchanger through the inner section of concentric ducting at the support level, close to the bottom of the cylindrical section of the shell. The gas stream turns upwards through an isolating valve into a vertical duct about 7 ft square, containing the cooling surface. At the top of the duct, the cooled gas emerges to flow downwards in the spaces between the duct and the outer shell, to be collected in a conical section leading to the eye of a single-stage, vertical spindle, centrifugal blower mounted in the bottom of the exchanger. The gas discharged from the blower passes through a diffuser into the annular space outside the cone via an isolating valve to the outer portion of the concentric duct leaving the exchanger.

Shell Design

The shells are manufactured from plates with a manganese content of 0.90-1.40% giving a U.T.S. of 28/34 tons/sq. in. and a minimum impact value of 20 ft lb at −10°C. The ruling thickness of the shells is $1\frac{7}{16}$ in. but the strake carrying the support feet is thickened to $2\frac{1}{2}$ in. All main connections to the shell comprise forgings which are designed to reinforce the shell opening and are also flanged so that welds, in line with main seams, can be subjected to 100% X-ray examination.

Each shell is divided into three sections to limit the transport and lifting weights, the sections being ultimately joined by seal welded flanges. After the three individual sections of the shell have been stress relieved, they are assembled into a complete unit. The flanged joints are bolted up, and all openings are blanked. The shell is then filled with water and hydrostatically tested to a pressure of 450 p.s.i.

The shell is then again split into the three sections so that the internal surfaces can be thoroughly cleaned prior to the insertion of the elements and other internal fittings in the Clean Conditions Shop, specially erected for the purpose at the company's Derby works.

Tubing

The cooling system for the gas comprises a single pressure steam generator, consisting of superheater, evaporator and economizer sections in the direction of gas flow. The economizers and superheaters are in contraflow and, as gas flow is upwards, this has involved maintaining rather high water velocities in the economizer to avoid gas leaving temperature fluctuations at low loads. The evaporator sections are in parallel flow, i.e., upward steam and water flow, and due to the low head available, assisted circulation has been adopted.

The economizer and evaporator tubing is Tube Products' 2-in. o.d. electrically resistance welded mild steel tube with six $\frac{1}{2}$-in. high helical fins per in., resistance welded to the

external surface. The superheater is 2¼% Cr, 1% Mo, 2-in. o.d. plain tubing. Although temperature conditions at the superheater inlet do not justify the use of this alloy from stress considerations, it was adopted throughout to avoid risk of the formation of scale. For similar reasons the fin material of the evaporator section is of silicon killed steel.

pressure shell, the connections being made by thermal sleeves to reduce temperature stresses, in a manner similar to the Calder Hall exchangers.

After fabrication and before assembly in the shells, every weld in each element is radiographically examined. The elements are then internally washed, hydraulically tested,

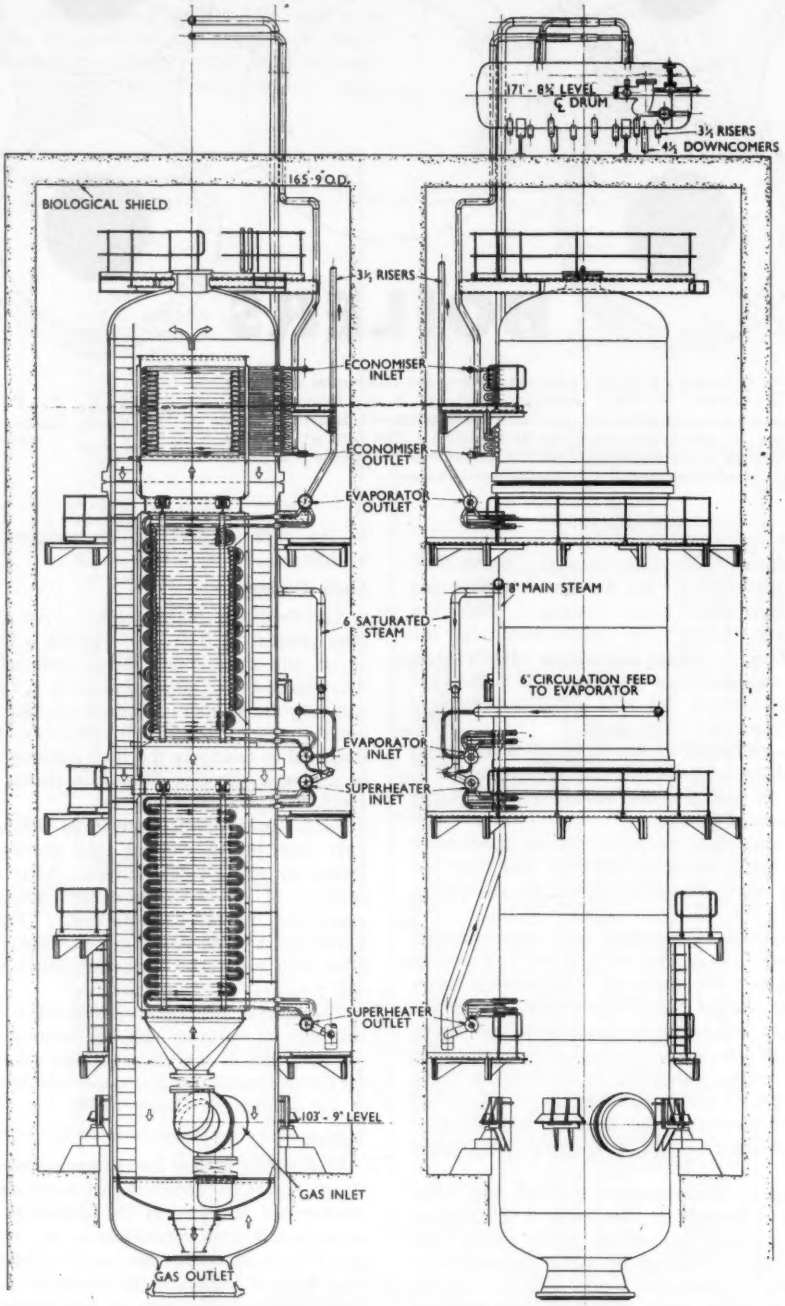


Fig. 1.—General arrangement of a pair of heat exchangers viewed in the direction of the arrow shown on the previous page.

Each heat exchanger is enclosed by a biological shield of concrete, the two shields being joined on the near side.

The tubing of all sections is fabricated into elements consisting of horizontal straight lengths of finned tube joined by plain bonds, the elements being arranged in "in-line" pitch to keep gas pressure drop to a minimum. The elements are joined into pairs by bifurcations at inlet and outlet to reduce the number of perforations of the

leak tested under vacuum, externally cleaned and assembled in the shell under clean conditions. The restricted space available in the shell makes necessary the most careful planning of the sequence and method of erection of the elements, supports, ducting and internal insulation. The basis of the method is partially to erect the casing members

and to introduce the elements working from the wings towards the centre. The elements are handled in a removable runway and are then jacked into position with the stubs projecting through the thermal sleeves whose blank caps are removed for the purpose. When all the elements are erected, the casing is completed. This demands the highest standard of accuracy in manufacture as gas leakage would interfere seriously with the heat exchanger performance and no form of resilient packing or seal welding can be used. The elements are then seal-welded to the tips of the thermal sleeves.

The boiler drum is mounted outside and on top of the biological shield of its own exchanger. The downcomer piping and circulating pumps are also situated outside the shield so that any routine maintenance can be carried out when the unit is operating. The passage of the circulating pumps, discharge pipes, risers, drains, etc., through the shield walls is sealed by means of flexible bellows members so that the shield can act as a primary containment should a leak develop anywhere in the system. Access can of course be obtained into the shielded area when the unit is shut down and access ladders and galleries are provided to the headers and access openings where necessary.

Control

The exchangers are required to maintain the gas temperature to the reactor over a wide range of conditions. The reactor is designed for the possible utilization of a number of different types of fuel element canning materials and, in consequence, a wide range of gas temperatures has to be catered for.

Primary control of leaving temperature is provided by the gas by-pass. This is pre-set for any given set of operating temperatures, but is not intended to be altered during a run. One somewhat unusual feature in connection with the by-pass is that, at low loads the pressure drop through the tube bank is less than the head caused by the temperature difference between the hot and cold legs, and to avoid loss of control it has been necessary to carry the by-pass ducts to the top of the exchanger.

Major Reactor Parameters and Steam Cycle Data

Reactor heat rate	100 MW
Net electrical output	approx. 28 MW(E)
Gas pressure at reactor inlet	270 p.s.i.g.
Gas temperature at reactor inlet	250°C rising to 325°C
Bulk gas outlet temperature	500°C rising to 575°C
No. of external circuits	4
No. of main circulators	4
Power of circulator coupling	approx. 1,200 h.p.
Steam cycle	single pressure
Feedwater temperature	variable
Superheater outlet pressure	620-670 p.s.i.g.
Superheater outlet temperature	860°F (460°C)
Dump condenser rating	100 MW

Control of gas-leaving temperature under load variation is carried out by feed temperature regulation. Hot and cold feed mains are brought to two three-element controlled feed regulating valves, the required feed temperature to the economizer being produced by biasing the valve openings. Steam temperature is controlled by a spray desuperheater in the main steam pipe.

One unusual feature of the steam side is that all safety valves are mounted on the superheated steam main. The pressure drop between drum and safety valves naturally introduces complications which have been carefully assessed, but it has the advantage that the valves can be outside the secondary containment which does not have to be pierced for the escape pipes.

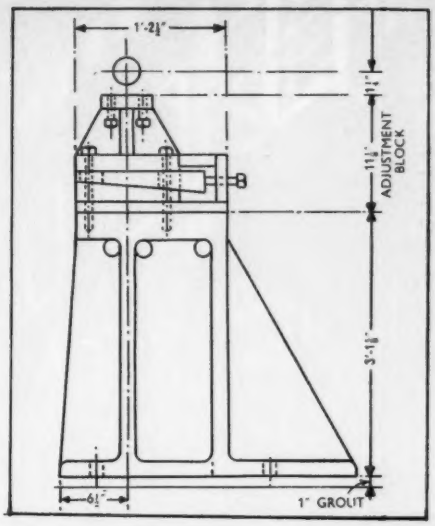


Fig. 2.—Side elevation of support fitted with a wedge combination facilitating adjustment to the required height.

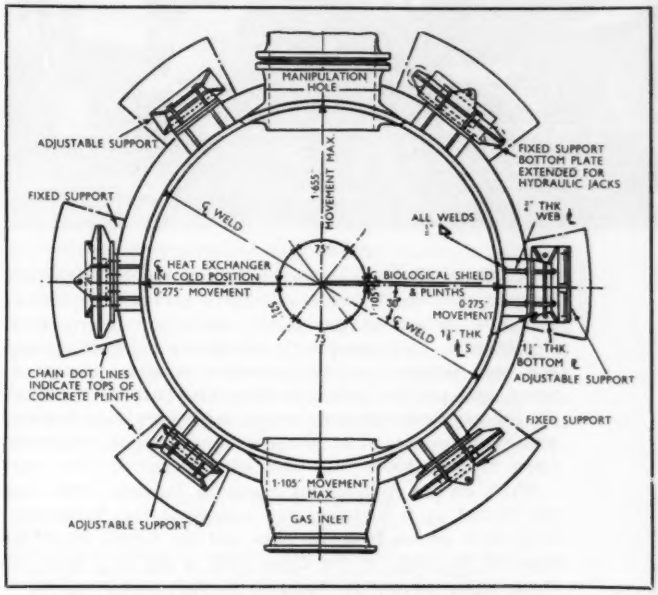
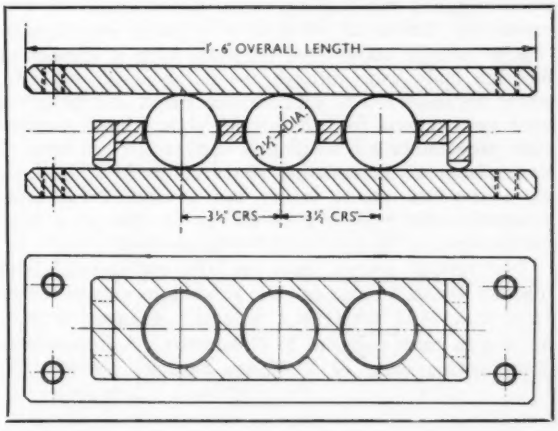
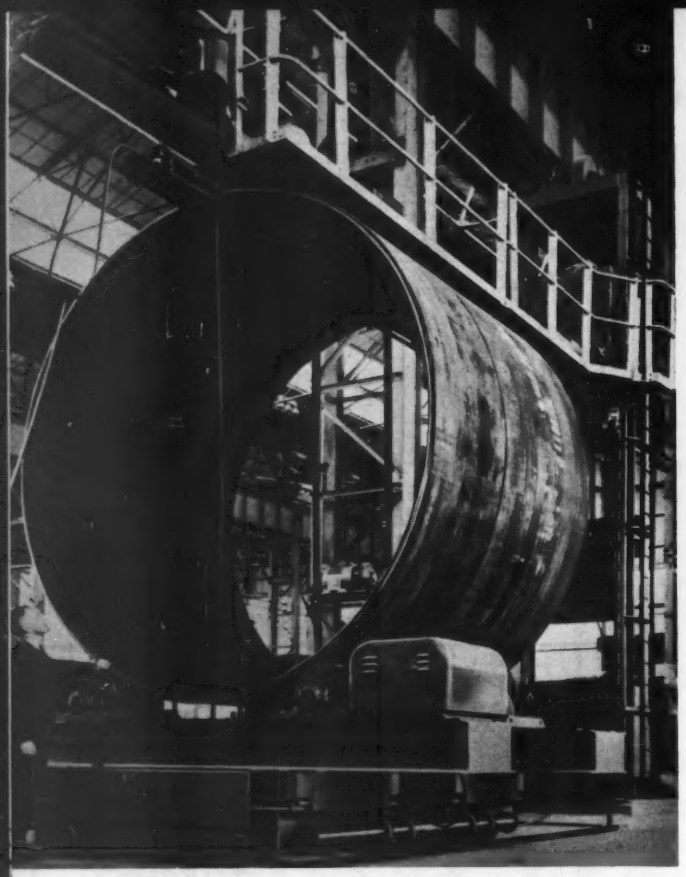
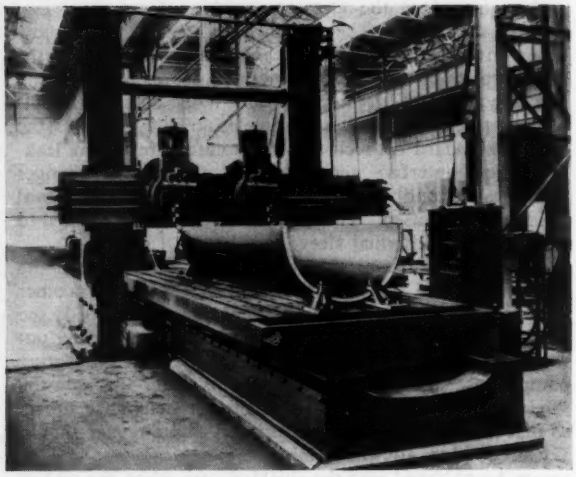


Fig. 3.—Details of the arrangement of the heat exchanger supports, each diametrically opposed pair consisting of one fixed and one adjustable support.

Fig. 4.—The ball bearing forming part of the supports to allow freedom of movement by the heat exchanger shell, caused by thermal expansion.







(Left) Automatic welder with rising boom for welding vessels up to 12½ ft diameter (Quasi-Arc).

(Above) Welding edges are prepared on a planer with a 25-ft bed.

Heat Exchanger Fabrication

International Combustion have recently inaugurated excellent new facilities for producing large-diameter pressure vessels at their Derby works.

EXCELLENT facilities for the fabrication of heavy-duty pressure vessels such as boilers for power reactors are now in use at the Derby works of International Combustion. The company's new heavy engineering shop has been designed so that pressure vessels for conventional and nuclear power stations and for the chemical, the refinery and similar industries can all be manufactured with equal ease. The shop—fully equipped with the latest machine tools—was completed in record time.

Work on the foundations began in January, 1958, and the 68,250 sq ft building was completed last September. It is built up on concrete piles and the height from the floor of the shop to the crane rails is 40 ft. There are three bays, the centre being 75 ft and each wing 65 ft wide; the overall length is 350 ft. A feature of the building is the thermal insulation provided by double panelling of the window glazing, the general panel, and the roof covering.

Layout of machinery around the shop perimeter is suited to the progressive stages of manufacture involved when handling heavy plate; each bay is served by two cranes, the heavier of which is of 50 ton lifting capacity.

Raw material taken from the stock yard is transferred into the main shop through the flame planer building, where the plates can be cut to size or shape, and the initial weld preparations formed on the plate edges. Further edge preparation for welding is carried out on either a large planer accommodating plates up to 35 ft long, or on a standard planer which has a table 25 ft long. Circumferential weld preparation can be done on a large centre lathe, or on a vertical boring machine.

Two vertical presses, each of 3,000 ton capacity, can together handle a range of plate bending in various widths from 3 in. thick (cold) at a minimum diameter of 3 ft, up to 4 in. thick (cold) at 25 ft diameter. A four-column downstroking press of 2,000 ton capacity provides for the hot pressing of dished ends and segments for all diameters of vessels and drums. Lighter sections of plate up to 1½ in. in thickness can be manipulated in the power rolls.

The principal welding machine is an automatic welder with a rising boom catering for vessels up to 12½ ft diameter, and 50 ft long. Vessels can be manipulated under the welding head by means of a roller bed installation, and there is provision for pre-heating. Other welding machines include self-propelled automatic units together with standard direct current and alternating sets.

To allow additional headroom for the construction of very large diameter vessels, the centre bay contains a welding pit 150 ft long by 25 ft wide by 12 ft deep. The floor of the pit carries manipulating equipment for rotating vessel sections during seam welding, and also provides adequately screened space for X-ray examination.

A group of three furnaces, centralized at the south end of the shop, handles the heating of plates for dishing and the heat treatment of either long or medium diameter vessels, or of large diameter sections of vessels. They are all gas fired and have fully automatic control for temperature regulation and the process is recorded throughout.

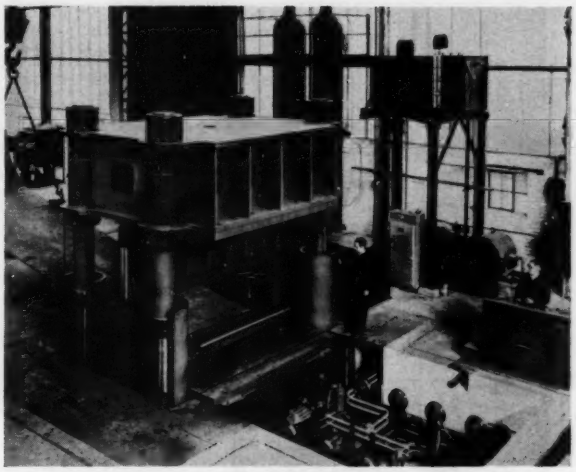
The large vertical borer can be adjusted to take work up to 25 ft in diameter and is used for cylindrical edge preparation, general boring and facing. There is also a

floor boring machine with a 3 in. diameter spindle. Tube hole drilling, and profiling tube stubs for welding, are catered for by a duplex horizontal boring machine. Further drilling machines for angular boring, facing and plate drilling are also installed.

On the east side of the heavy engineering shop, a separate clean conditions building has been erected in which the final assembly of heat exchangers and similar vessels for nuclear work will be undertaken in booths which are completely isolated and fully air conditioned. The clean conditions building will be put to immediate use for the heat exchangers which are being manufactured by International Combustion for the Advanced Gas Cooled Reactor. These heat exchangers represent a departure from previous practice in the nuclear field as they have been specifically designed to reduce site work to a minimum. Not only has this meant that such a building must be located at the manufacturers' works, but also that each section should be kept to a transportable size and within crane capacity.

Before the elements of a heat exchanger reach the clean conditions room, they are degreased by complete immersion in trichlorethylene, followed by suspension in vapour. This ensures that all grease is removed from the bores and also any deposited on the external surface due to handling during fabrication, thus meeting an essential prerequisite for vacuum leak testing. The completed element is hydraulically proved and then subjected to vacuum leak testing, with inter-stage hot air circulation until all the moisture has been evaporated. Final cleaning of the elements is accomplished in an ultrasonic bath using trichlorethylene as the operating medium. It has been necessary to provide adequate ventilation for the plant but it has also been found that this process of cleaning is quicker than shot blasting. Tests have been carried out satisfactorily and have met clients' requirements. However, the internal surface of the shell and all casing and steel work are shot blasted (with Vacu Blast equipment) prior to entry into the main building.

The shells are brought from the main shop to the shot blast, thence to one of the openings in the room. Sealing is effected by an external plate which covers the hole both before the shell is first attached and when it is finally removed for transport to site. During the assembly of the internals, the seal is achieved by interposing a rubber ring from the room face to the shell flange. All other shell openings are, of course, sealed. The shop has been arranged so that the shells are under cover the whole time and this, apart from protecting the vessels, also assists in seal welding the thermal sleeves and in attaching the external headers. The shell internals are placed into position with the use of a runway beam which lines up with the overhead crane, thus reducing handling to a minimum. Such time that has been lost in lifting and lowering components into position in previous projects of this nature is now saved by this layout.



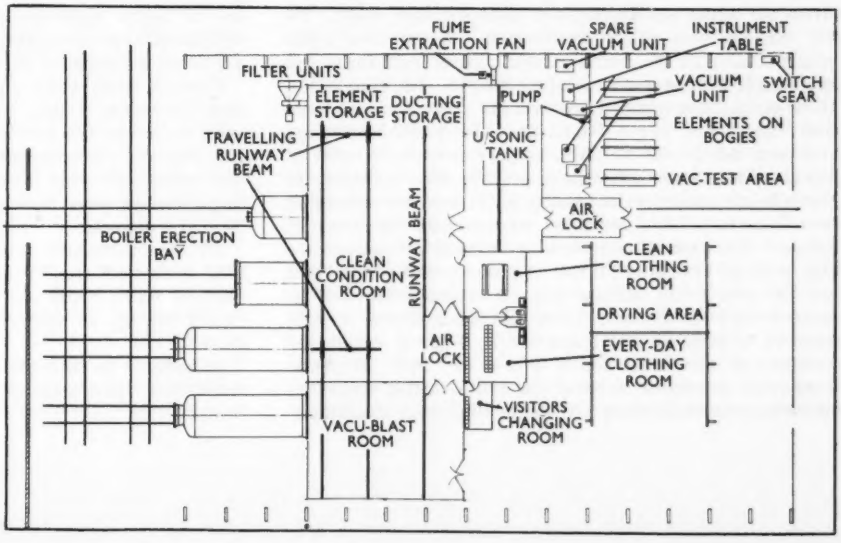
Flanging press of 2,000-ton capacity supplied by Fielding and Platt.

The erection of the clean conditions building at ground level has permitted a generous allocation of floor space and the provision of a manually operated crane. There is ample storage space for elements and the fitting of reflective insulation can be carried out in the same room. The fact that all the work is undertaken in one building encourages co-ordination and should result in efficient productive effort. As is the usual practice, the building is pressurized to prevent the ingress of foreign material.

Apart from the new heavy engineering shop and the clean conditions building, International Combustion have also extended their laboratory departments and rationalized their research activities. The company has always paid great attention to methods of non-destructive testing and X-ray and gamma techniques are in constant use.

PRINCIPAL CONTRACTORS

GEE, WALKER AND SLATER LTD., building—civil work.
REDPATH BROWN AND CO. LTD., building—structure.
DRUMMOND-ASQUITH (SALES), LTD., horizontal boring machines.
GEORGE RICHARDS AND CO. LTD., vertical boring machines.
JOSEPH BOOTH AND BROS., electric overhead travelling cranes.
DOWSON MASON LTD., furnaces.
QUASI-ARC LTD., boom welder.
HANCOCK AND CO. (ENGINEERS), LTD., flame planing machine.
FIELDING AND PLATT LTD., presses.
JERRAM AND CO. LTD., piping and services.
CROMPTON PARKINSON LTD., switchgear, cables and electrical auxiliaries.



Layout of the clean conditions building adjacent to the heavy engineering shop.

radwell Power Station.

oliath crane ting first seg- ent of No. 1 actor pressure vessel.

Whessoe Ltd.

for Reactors and Processing Plants

Mild steels are being used in plate thicknesses up to 4 in. for reactor pressure vessels. Stainless steels are used for chemical plant, liquid metal circuits, and are being considered as canning materials.

By **E. WATKINS**, M.Sc., A.I.M.
(Culcheth Laboratories, Development and Engineering Group, U.K., AEA)

THE development of the gas-cooled reactors has necessitated the construction of pressure vessels up to 70 ft dia. in 2–4 in. steel plate. This presents difficulties in site welding and at present the choice of steel is restricted to either an aluminium-killed grain-size-controlled steel or a silicon-killed mild steel. Unless shell cooling or insulation is incorporated in the design, the top dome of a reactor will attain the outlet gas temperature, approximately 400°C, for the reactors now under construction. If excessive creep occurs fouling of the discharge and control mechanism can affect the continued operation of the reactor. The aluminium-killed grain-size-controlled steel will not allow an operational shell temperature above 340°C, and silicon-killed steels are at present being used for shell temperatures of the order of 400°C. These latter steels have not the same resistance to brittle fracture and the site welding and fabrication techniques have been carefully controlled to minimize the risks of failure. While the reactor pressure vessel is not subject to a high level of irradiation, direct inspection of the vessel will not be possible in service and no maintenance can be contemplated at present. This has necessitated a high standard of welding and inspection in order to ensure the integrity of the vessel for a life of at least 20 years. Irradiation is known to raise the brittle-ductile transition temperature of mild steels and the possibility of irradiation-induced precipitation and structural changes which could affect both the high temperature and room temperature strength and ductility needs consideration.

The steels used for the civil reactors now under construction in the United Kingdom are of the mild steel type, but low alloy steels with good notch ductility and high temperature properties are under development. These could allow the use of higher shell temperatures and yet keep within the stipulated creep limitations. Insufficient data and experience are as yet available to allow the use of these new steels.

Pressure shells which are not subjected to irradiation, e.g. heat exchanger vessels and containment vessels, do not present such serious problems as the reactor pressure vessels. Nevertheless, the consequences of failure would be serious, and considerable care is exercised during the fabrication and inspection of these vessels, which can be of the order of 80×20 ft diameter in 3 in. plate.

At the operational temperature of 400°C, corrosion of mild steels with coolant gas is not serious but the development of liquid metal and water-cooled reactors has necessitated the use of stainless steel and low alloy chromium steels.

In addition to their use for reactor construction, stainless steels have been used as containment vessels in chemical plants.

The processes for the extraction of uranium and plutonium are both based on treatment in nitric acid. The radioactive and toxic hazards involved in the extraction of uranium are not very great, and an 18/8/Ti steel was used for the Springfields extraction plant. The extraction of plutonium on the other hand involves the use of highly radioactive and toxic material and this necessitated the development of the 18/13/Nb steel which is even more resistant to the corrosive action of the reagents used.

Compared with other canning materials the neutron absorption cross-section of stainless steels is high, but due to their good corrosion resistance and increased strength at elevated temperatures they have been considered as canning materials for the advanced gas-cooled, liquid metal, and pressurized water reactors.

PHYSICAL PROPERTIES

The physical properties of steels are dependent on carbon and alloy content and on the previous heat treatment. These factors affect the phase transformations which occur in steels on heating and cooling. In commercially pure iron, the stable form at room temperature is body-centred cubic (b.c.c.) alpha iron (ferrite). On heating to 910°C alpha iron transforms spontaneously to a face-centred cubic (f.c.c.) structure, gamma iron (austenite). On heating, austenite itself transforms to another b.c.c. form, delta iron, at 1400°C. The equilibrium solubility of carbon in ferrite or alpha iron at room temperature is extremely low, but on heating to the gamma range there is a marked increase in carbon solubility. The transformation temperature of gamma-alpha iron is reduced from 910°C in the case of pure iron, to 721°C for iron containing 0.87%C, the eutectoid composition. Due to the very low solubility of carbon in ferrite at room temperature the bulk of the carbon present in commercial steels is in the form of pearlite, a eutectoid mixture of cementite (Fe_3C) and alpha iron.

The gamma-alpha phase transformation is important as it is the basis of the normalizing treatment (applied to commercial steels) and due to its contribution to the varying properties across the heat affected zone of welds in ferritic steels. Rapid cooling or the addition of certain alloying elements suppresses the transformation temperature, and with extremely rapid cooling of austenite, the formation of pearlite is completely suppressed and tetragonal martensite is formed. This is a hard metastable form of alpha iron in which distortion of the crystal structure has been produced by the supersaturation of dissolved carbon atoms. Generally speaking, the lower the temperature of transformation, the harder and less ductile the product in the as-transformed condition.

In the case of the 18/13 types of stainless steel the gamma-alpha transformation is entirely suppressed and austenite is the stable form at room temperature. With lower nickel contents as in 18/8 types of steel, the alloys are not fully austenitic and up to 15% of ferrite can be formed on slow cooling. The quantity of ferrite formed is, however, dependent on the heat treatment, especially the rate of cooling.

The coefficient of linear expansion of austenitic stainless steel is approximately 50% greater than that of ferritic steel, and the coefficients for both types of steel increase with rise of temperature. The thermal conductivity[2] of austenitic stainless steels increases from 0.039 g cal/cm,sec,°C at 100°C to 0.061 g cal/cm,sec,°C at 700°C, while that of the mild steel decreases from 0.122 g cal/cm,sec,°C at 100°C to 0.076 g cal/cm,sec,°C at 700°C. The combination of high coefficient of thermal expansion and low conductivity of the austenitic steels can lead to high fatigue stresses under conditions of thermal cycling. Special allowance must be made in design to allow for the differential expansion of austenitic and ferritic steels when both types are used concurrently in any component or plant.

The 18/13 type of austenitic steels is virtually non-magnetic but the magnetic properties of the 18/8 type of steel are dependent on the amount of ferrite or martensite present in the structure. This is in turn dependent on composition, heat treatment and cold work. Little information is published on the magnetic properties of these alloys but Keating's[3] values are given in Table 1.

Table 1—Magnetic Permeability of 18/8 Type Steels for Field Strengths of 50-500 Gauss

Material	Magnetic Permeability	
	Softened	10% Cold Stretched
18/8	1.005—1.03	1.08—1.13
18/8/Ti	1.5 —2.0	—

MECHANICAL PROPERTIES

Tensile Properties

Pressure vessels designed in accordance with British Standards have maximum permissible working stresses based on 25% of the specified minimum ultimate strength at room temperature. At temperatures within the creep range designs must be based on creep data in conjunction with the stress rupture properties and other relevant high temperature properties. The steels being used at present have ultimate tensile strengths in the range 28/32 ton/in.^{2}; yield strength 15/19 ton/in.^{2}; elongations 25/45% on $4\sqrt{A}$. This has necessitated the use of plate thicknesses of 2 to 4 in.

28/32 *ton/in.^{2} Tensile Strength Ferritic Steels.* In this tensile range the choice of steel is at present restricted to either an Al-killed grain-size-controlled mild steel or a coarse grained silicon-killed mild steel. In the conventional tensile test both types of steel can show similar properties but differences are observed in either the notched tensile or notch bend tests. If a series of notched tests is performed over a range of temperatures, the fracture characteristics change suddenly with reduction in temperature from a shear or ductile fracture, with considerable reduction of area and high energy absorption, to a cleavage or brittle fracture with little or no reduction in area and low energy absorption. This change or transition in the mode of fracture is accompanied by a change in fracture appearance from a fibrous to a crystalline texture with falling temperature. The transition can occur within a narrow temperature band less than 10°C, or over a range greater than 80°C, depending on test piece type and geometry. Fig. 1 illustrates the transition temperature of the Al-killed and Si-killed steel in the Charpy Vee notch impact test.

The transition temperature of a steel in a given type of test is dependent on composition, steel making practice, subsequent mechanical working and heat treatment. Increase of the manganese-carbon ratio, fixation of nitrogen, and refinement of the grain structure, e.g. by normalizing, all lower the transition temperature and so reduce the tendency to catastrophic brittle failure under any given set of conditions.

For steel in the as-rolled condition, the transition temperature, as determined in any one test, is dependent on the finishing temperature of rolling. The higher the finishing temperature, the higher the transition temperature. MacKenzie[4] has shown that for mild steel plates an increase of plate thickness from ½ in.–1½ in. raises the 15 ft lb transition temperature in the Charpy Vee notch impact test by as much as 60°C. This is largely due to the coarse ferritic grain size

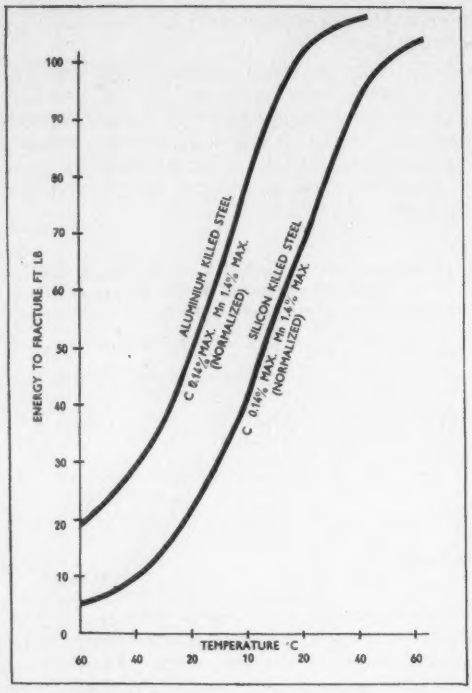

ENERGY TO FRACTURE FT LB
TEMPERATURE °C
ALUMINIUM KILLED STEEL
C 0.14% MAX. Mn 1.4% MAX. (NORMALIZED)
SILICON KILLED STEEL
C 0.14% MAX. Mn 1.4% MAX. (NORMALIZED)

Fig. 1 (left).—Typical Charpy Vee notch impact energy transition curves for mild steel.

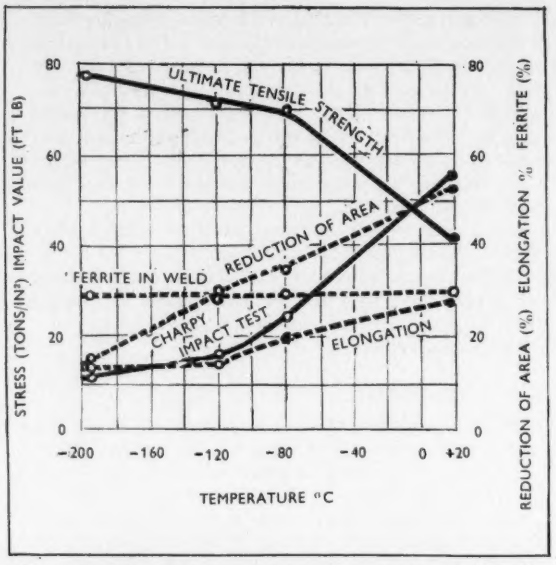


Fig. 2 (above).—Sub-zero mechanical properties of 18/8/Nb weld deposit on $\frac{3}{4}$ in. thick 18/8/Ti plate. Composition of the deposit: 0.08%C, 0.5%Si, 1.2%Mn, 20%Cr, 8.9%Ni, <0.05%Mo, 0.89%Nb (Keating[3]).

produced by the higher finishing temperature of the thicker plates. Normalizing tends to even out the effect of plate thickness, although, due to the slower rate of cooling through the transformation range, the transition temperature, even after normalizing, rises with increase of plate thickness.

Apart from the metallurgical factors discussed above, increasing the test piece size can have other effects. For a given distribution of defects, the probability that a particular size defect will occur in a specimen increases with specimen size, hence the larger test pieces may fail before smaller ones. Other considerations which could account for this size effect relate to the increase in surface area and the increase in available elastic strain energy. Due to these factors, many investigations have shown that the transition temperature is increased as the test piece size is increased. It is difficult to isolate the metallurgical factor from other influences but it is considered possible that this size effect is not entirely due to purely metallurgical phenomena. Fig. 3 (a and b) shows the increase in transition temperature with increase in test piece size for un-notched[5] and Charpy Vee notch[6] types of specimen respectively.

For practical convenience the transition temperature is generally determined by one of the small scale notch ductility tests, although the transition given by any one type of test is not necessarily an accurate indication of the service behaviour. Attempts have been made to correlate small scale notch ductility tests with service failures, and some measure of success has been claimed for the Charpy Vee notch impact test[7], the Tipper notch tensile test[8] and the Pellini Drop Weight test[9]. These results relate in the main to service failure in plate of the order of 1 in. thickness.

Crack propagation tests have also been used to give some indication of the relative merits of steels. The test devised by Robertson[10] shows that under the test conditions the stress necessary to propagate a brittle fracture increases sharply at what is termed the " ductility arrest temperature." Very little experimental information is available on the arrest temperatures of 3 in. plates but recent tests by Colvilles[11] quote −27°C and −10°C for the aluminium-killed and silicon-killed steel, respectively.

Due to the metallurgical and size effects referred to, the use of full plate thickness tests is advocated for correlating laboratory tests with service failures. In order to avoid the undue influence of the initiating notch, wide plate tests are to be preferred and Tipper[12] advocates a width-to-thickness ratio of not less than 2:1. When a fracture has started propagating, the extent of cracking is largely governed by the stored elastic energy. If the release of elastic strain energy per unit area is less than the work expended in spreading the crack per unit area, then the fracture cannot propagate, but, if larger, a catastrophic failure will occur.

The benefits of stress relief in minimizing the risk of catastrophic brittle failure have been clearly demonstrated by Wells[13] who showed that relief of residual stress increased the applied stress necessary to propagate brittle fracture in his wide plate test.

In large vessels the stored elastic energy is such that stress relief does not in itself remove the risk of brittle fracture, and two stress relieved vessels are known to have failed in a brittle manner[9].

Stainless Steels. Fully austenitic stainless steels do no

Table 2—Stress in ton/in.² to give 0.1% and 0.5% Creep in 10^5 h for Two Grades of C-Mn Steel in the As-rolled Condition

Temperature °C	Steam Pipe Material* 0.1%	0.5% Creep	Superheater Material† 0.1%	0.5% Creep
415	—	—	4.3	—
425	—	—	2.5	4.0
440	4.7	—	1.7	2.5
455	3.6	5.1	1.3	1.6
465	3.1	4.8	1.3	1.25

* Composition: 0.135%C, 0.18%Si, 0.47%Mn, deoxidized Al, Ferro-Mn and Ferro-Si.

† Composition: 0.12%C, 0.04%Si, 0.45%Mn, deoxidized 2 lb Al/ton.

Nuclear Engineering

DATA SHEET

No 14. Steel

The information on this sheet covers three groups of steel as follows:

(a) Ferritic (mild) steels of varying composition.

(b) Low-alloy Cr-Mo steels of the composition: 1% Cr ½% Mo and 2¼% Cr 1% Mo.

(c) Austenitic (stainless) steels of the composition: 18% Cr 8% Ni and 18% Cr 12% Ni with the addition of up to 1% Ti or Nb as carbide stabilizers.

Symbol .. .. Fe

Atomic number 26

Atomic weight 55.58

Melting point .. .. 1527°C

Young's modulus .. .. 30×10^6 lb/in.²

Poisson ratio 0.29

Crystal structure

alpha iron (0—910°C) .. .. body centred cubic a=2.8604 kX at 20°C

gamma iron (910—1405°C) .. .. .. face centred cubic a=3.64 kX at 910°C

delta iron (1405—1527°C) .. .. body centred cubic a=2.93 kX at 1400°C

iron carbide (Fe_3C) .. .. orthorhombic a=4.5155 ; b=5.0773 ; c=6.7265 kX at 25°C

The variation of the lattice parameter of gamma iron with carbon content in the range of 750—1100°C can be expressed approximately by the relationship .. .. $0.0027 \times (\%C \times 10)^2$

A. IRRADIATION EFFECTS

TABLE A1(34)

Effect of Irradiation on Mechanical Properties of A.S.T.M. A212 Grade B, Carbon Silicon Steel.

Composition: 0.31–0.75%C, 0.9% max. Mn, 0.04% max. P, 0.05% max. S, 0.15–0.30% Si.

Irradiation n.v.t.	Yield strength ton/in.²	Tensile strength ton/in.²	Reduction of area %	Uniform elongation % to necking
0	22.2	33.5	64	22
10^{19} at 60°C	28.9	36.1	68	18
10^{19} at 298°C	25.3	37.4	57	12
10^{20} at 80°C	41.9	43.1	26	5

B. PHYSICAL PROPERTIES

TABLE B1(2)

Heat Required to Raise Steel from 50°C to Temperatures shown

Temperature °C	0.08%C (killed) cal/g	0.23%C (killed) cal/g	18/8 Stainless cal/g
100	5.8	5.8	6.1
200	18.0	18.0	18.8
300	31.1	31.0	31.8
400	45.0	45.0	45.2
500	60.4	60.4	59.3
600	77.6	77.7	74.6
700	97.2	97.2	89.6
800	122.3	125.7	104.7
900	142.3	142.2	120.1

TABLE B2(2)

Mean Coefficient of Thermal Expansion, per °C

Temperature range °C	0.08%C (killed) $\times 10^6$	0.23%C (killed) $\times 10^6$	18/8 Stainless $\times 10^6$
0–100	12.19	12.18	14.82
0–200	12.99	12.66	16.47
0–300	13.51	13.08	17.11
0–400	13.91	13.47	17.61
0–500	14.30	13.92	18.04
0–600	14.68	14.41	18.43
0–700	15.05	14.88	18.77
0–800	14.79	12.64	19.03
0–900	12.60	12.41	19.21

TABLE B3(2)

Thermal Conductivities of Steels

Temperature °C	0.08%C (killed) g, cal/cm, sec, °C	0.23%C (killed) g, cal/cm, sec, °C	18/8 Stainless g, cal/cm, sec, °C
0	0.142	0.124	0.038
100	0.138	0.122	0.039
200	0.128	0.116	0.041
300	0.118	0.106	0.044
400	0.107	0.102	0.048
500	0.096	0.094	0.052
600	0.086	0.085	0.057
700	0.076	0.076	0.061
800	0.068	0.062	0.064
900	0.064	0.063	0.064

TABLE B4(2)

Electrical Resistivity

Temperature °C	0.08%C (killed) microhm, cm	0.23%C (killed) microhm, cm	18/8 Stainless microhm, cm
0	13.2	15.9	69.4
100	19.0	21.9	77.6
200	26.3	29.2	85.0
300	35.2	38.1	91.6
400	45.8	48.7	97.6
500	58.4	60.1	102.6
600	73.4	75.8	107.2
700	90.5	92.5	111.1
800	108.1	109.4	114.1
900	113.0	113.6	117.1

TABLE B5(2)

Densities

Temperature °C	0.08%C (killed) g/cm³	0.23%C (killed) g/cm³	18/8 Stainless g/cm³
0	7.861	7.863	7.921
100	7.832	7.834	7.886
200	7.800	7.803	7.843
300	7.765	7.770	7.799
400	7.730	7.736	7.754
500	7.692	7.699	7.707
600	7.653	7.659	7.658
700	7.613	7.617	7.609
800	7.582	7.624	7.559
900	7.594	7.600	7.510

TABLE A2(34)—Effect of Irradiation on Properties of Austenitic Stainless Steels*

Alloy No.	Composition†	Controls—C Irradiated specimens—I	Yield stress 0.2% ton/in.²	Ultimate tensile strength ton/in.²	Reduction of area %	Elongation %	Hardness Rockwell B	A.S.T.M. grain size
301	16–18% Cr/6–8% Ni+Mn	C.	18.2	43.9	83	56	80	2
		I.	38.7	50.0	81	48	94	–
302	17–19% Cr/8–10% Ni+Mn	C.	14.9	42.2	—	—	74	4
		I.	37.3	49.1	—	—	94	—
302 B	17–19% Cr/8–10% Ni+Mn+ 2–3% Si	C.	14.7	47.7	—	—	78	4
		I.	36.3	56.0	—	—	97	–
304 ELC*	18–20% Cr/8–11% Ni+Mn	C.	10.0	38.6	74	63	60	4
		I.	33.5	46.0	73	58	86	–
321*	17–19% Cr/8–11% Ni+Ti	C.	13.8	37.8	—	—	74	7
		I.	40.5	47.2	—	—	94	–
347	17–19% Cr/9–12% Ni+Nb	C.	16.6	43.5	71	49	81	8
		I.	43.0	50.9	62	25	99	–

* Alloys 304 ELC and 321 irradiated at 7.8×10^{19} n.v.t. (fast). Others irradiated at 3.9×10^{19} n.v.t. (fast). † Testing strain rate 0.05 in./in.,min.

S

eratures shown

18/8 Stainless cal/g
6.1
18.8
31.8
45.2
59.3
74.6
89.6
104.7
120.1

per °C

18/8 Stainless ×10⁶
14.82
16.47
17.11
17.61
18.04
18.43
18.77
19.03
19.21

18/8 Stainless g. cal/cm, sec, °C
0.038
0.039
0.041
0.044
0.048
0.052
0.057
0.061
0.064
0.064

18/8 Stainless microhm, cm
69.4
77.6
85.0
91.6
97.6
102.6
107.2
111.1
114.1
117.1

18/8 Stainless g/cm³
7.921
7.886
7.843
7.799
7.754
7.707
7.658
7.609
7.559
7.510

A.S.T.M. grain size
2
–
4
—
4
–
4
–
7
–
8
–

n.,min.

C. CHEMICAL PROPERTIES

TABLE C1

Oxidation of Mild Steel by Dry CO_2 at 8 atm and 400–600°C

Time h	Weight gain at 400°C mg/cm²	500°C mg/cm²	550°C mg/cm²	600°C mg/cm²
168	0.195	0.75	3.4	22.5
336	0.277	0.98	4.36	26.5
504	0.321	1.21	5.5	30.7
672	0.356	1.49	6.25	32.6
840	0.390	1.81	6.70	32.7
1008	0.449	1.98	7.66	34.1
1176	0.450	2.16	8.47	37.2
1344	0.454	2.28	9.30	—
1436	—	—	—	41.6
1512	0.460	2.39	—	—
1680	0.468	2.49	9.9	—
1772	—	—	—	47.8
1848	0.475	2.72	—	—
2016	0.482	—	10.8	—
2184	0.540	3.22	—	—

Stainless steels are compatible with CO_2 up to 600°C.

TABLE C2

Corrosion of Low Alloy Steel by Flowing Na at 400° and 550°C for 350 h. Oxygen Level—20 p.p.m.

Material	400°C wt. loss g/dm²	500°C wt. loss g/dm²	Flow rate ft/sec	Metallographic examination after 350 h at 550°C*
C–1% Mn steel, ...	0.00620	0.0534	5.5	complete decarburization
normalized	0.00465	0.0494	2.0	
normalized and stress relieved	0.00388	0.0513	5.5	(Specimen 0.028 in. thick)
1%Cr–½%Mo steel, ...	0.00745	0.0235	5.5	complete decarburization
normalized	0.00652	0.0238	2.2	
normalized and stress relieved	0.00202	0.0255	5.5	(Specimen 0.028 in. thick)
½%Mo–¼%V steel, ...	0.00279	0.0249	5.5	almost complete decarburization
normalized and tempered ..	0.00295	0.0271	4.0	
normalized and tempered and stress relieved	0.00496	0.0253	5.5	
2¼%Cr–1%Mo steel, ..	0.00573	0.0306	5.5	slight evidence of decarburization, the edge grains being mainly ferritic
annealed	0.00403	0.0254	4.0	
annealed and stress relieved ..	0.00171	0.0300	5.5	
2¼%Cr–1%Mo steel, ..	0.00512	0.0087	5.5	no evidence of decarburization observed
normalized and tempered ..	0.00620	0.0074	4.0	
normalized, tempered and stress relieved	0.00167	0.0112	5.5	

* No decarburization observed after 350 h at 400°C.

TABLE D5

Comparative Creep Strength of Steels—Group (a) and Group (b)

Type of steel	Heat treatment	Composition C %	Si %	Mn %	0.1% Creep in 10⁵ h Stress ton/in.²	Temperature °C	0.5% Creep in 10⁵ h Stress ton/in.²	Temperature °C
Mild steel	normalized	0.24	0.10	0.61*	5	443	5	450
		C %	Cr %	Mo %				
Low-alloy steel 1% Cr ½% Mo	normalized	0.12	0.75	0.5†	4	515	4	530
					6	462	6	505
Low-alloy steel 2¼% Cr 1% Mo	annealed at 940°C		2.5	1.0‡	4.7	535	5.8	550
							4.8	565

* see Reference 16.
† see Reference 17.
‡ see Reference 18.

TABLE D7

Tensile Tests on Austenitic
Composition: 18% Cr, 8% Ni and 18%

Ultimate Tensile Stress ton/in.²				Yield Stress ton/in.²		
Temperature	18/8	18/8/Ti	18/8/Nb	18/8	18/8/Ti	18/
20°C	37.9	37.9	40.6	15.2	14.7	1
370°C	29.4	26.5	29.9	7.4	10.3	1
480°C	26.8	25.0	28.6	6.7	9.1	1
590°C	21.9	21.9	25.0	5.8	8.5	1
700°C	15.8	16.5	17.9	4.9	7.4	1
815°C	9.4	9.8	10.3	4.5	5.8	1

D. MECHANICAL PROPERTIES

TABLE D1(46)

Tensile Properties of Ferritic Steel—Group (a)
Composition: 0.19%C, 0.68% Mn, 2.4 lb Al/ton. (Stress Relieved 2 h at 620°C)

Temperature °C	Tensile strength ton/in.²	Yield strength 0.2% offset ton/in.²	Elongation on 2 in. %	Reduction of area %
Room temperature	29.0	15.6	34	58.5
100	26.8	15.6	33.5	57.0
200	26.4	13.0	28.5	59.0
300	26.4	12.0	30	59.5
400	23.4	10.0	38	—
500	16.4	9.6	40	58.5

TABLE D2(46)

Tensile Properties of Ferritic Steel—Group (a)
Composition: 0.20%C, 0.66% Mn, 0.27% Si.
(Stress Relieved—2 h at 620°C)

Temperature °C	Tensile strength ton/in.²	Yield strength 0.2% proof stress ton/in.²	Elongation on 2 in. %	Reduction of area %
Room temperature	28.2	16.4	34.5	63.0
100	27.8	14.8	27.5	61.0
200	33.4	14.0	20.0	49.0
300	32.0	11.6	28.0	54.0
400	25.8	11.2	34	66
500	17.0	9.4	48	76

TABLE D3(47)

Tensile Properties of Steel—Group (b)
Composition: 1% Cr, ½% Mo

Temperature °C	Tensile strength ton/in.²	Yield strength 0.05% proof stress ton/in.²	Elongation $4\sqrt{A}$ %	Reduction of area %
20	34.4	11.4	41.0	63
400	39.6	11.3	33.0	62
450	36.9	12.5	30.0	63
510	33.0	11.1	35.3	68
538	30.9	10.7	36.7	68
565	26.9	9.9	35.3	73

TABLE D4(47)

Tensile Properties of Steel—Group (b)
Composition: 2¼% Cr, 1% Mo
Treatment: (A) normalized at 890°C and tempered at 734°C, (B) annealed at 930°C

Temperature °C	Tensile strength ton/in.²		Yield strength 0.1% proof stress ton/in.²		Elongation $4\sqrt{A}$ %		Reduction of area %	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
20	41.4	32.6	36.0	15.3	30.0	40	75	53
535	31.1	25.0	24.3	11.4	32.0	36.0	79	75
580	25.7	21.9	16.5	10.5	42.0	50.0	84	79
610	22.1	18.3	14.6	9.9	54.0	63.0	88	85

TABLE D6(22)

Tensile Tests on Austenitic Steel—Group (c)
Composition: 18% Cr, 12% Ni, 1% Nb

Temperature °C	Ultimate tensile strength ton/in.²	Yield strength 0.1% proof stress ton/in.²	Elongation $4\sqrt{A}$ %	Reduction of area %
20	36.8–42.5	12.5–14.4	52–59	60–65
400	28.0	10.0	36–40	51–65
500	26.1–27.5	9.5	33–35	47–66
600	23.5–26.6	9.2–11.7	37–42	52–64
700	19.3–21.5	8.8–10.3	40–44	60–65
800	15.0	8.3	54	60

TABLE D7(3)

on Austenitic Steel—Group (c)
, Ni and 18% Cr, 8% Ni, 1% Ti or 1% Nb

ld Stress on/in.²			Elongation %			Reduction of area %		
8/8/Ti	18/8/Nb	18/8	18/8/Ti	18/8/Nb	18/8	18/8/Ti	18/8/Nb
14.7	17.6	63	58	50	76	75	71
10.3	14.3	50	38	35	72	71	72
9.1	14.3	45	37	35	69	70	69
8.5	14.1	40	43	39	62	73	69
7.4	12.7	37	56	51	51	78	74
5.8	10.7	39	73	76	45	85	92

Nuclear Engineering

DATA SHEET

No. 14. Steel

Fig. 1 (below).—Temperature-log Time curves for specific creep strains at 5 ton/in². Material : Superheater—header Si-killed carbon steel. Composition : 0.24% C, 0.1% Si, 0.61% Mn, 0.032% S, 0.040% P. Normalized at 930°C. (Ridley 16.)

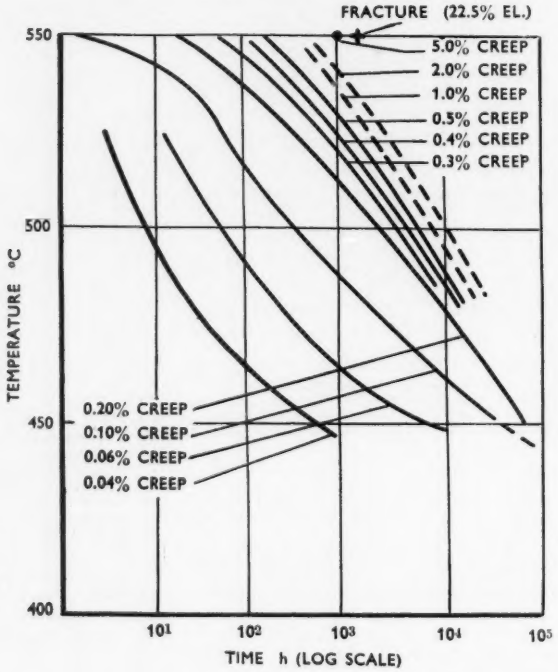


Fig. 2(a-c) (see next column).—(a) Temperature-log Time curves for specific creep strains and rupture. Material : Superheater—tube low-alloy steel. Composition : 2¼% Cr, 1% Mo. Annealed at 920°C. (Smith et al. 48.) (b-c) Log Stress-log Time curves for specific creep strains and rupture. Material: Steam-pipe low-alloy steel. Composition : 2¼% Cr, 1% Mo. Annealed at 930°C. (Smith et al. 48.)

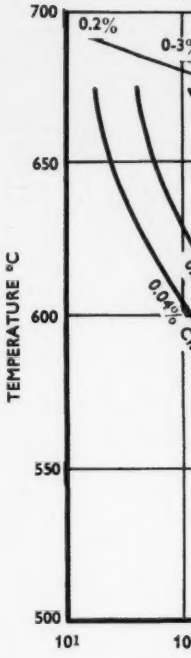
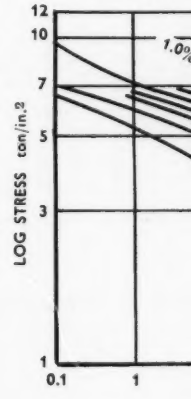


Fig. 2 (b) (ab



Creep Design Curves

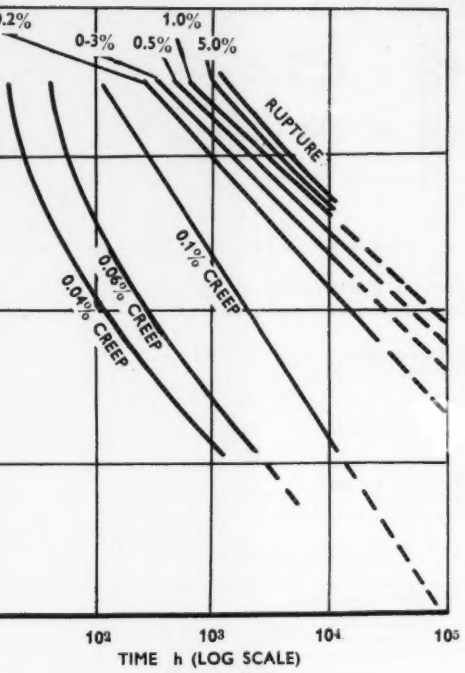


Fig. 2 (a).

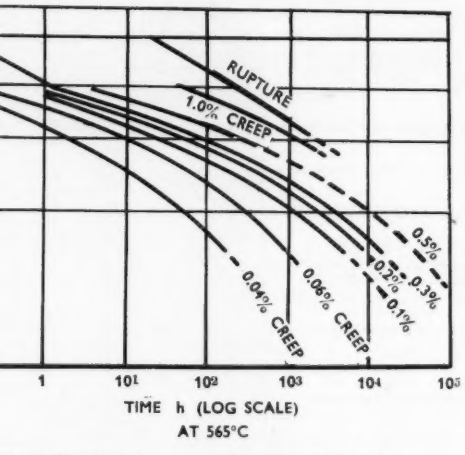


Fig. 2 (b) (above).

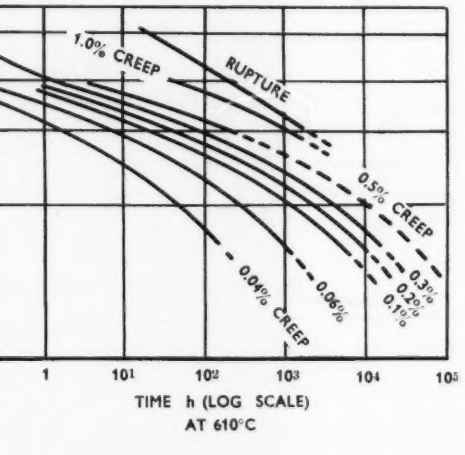
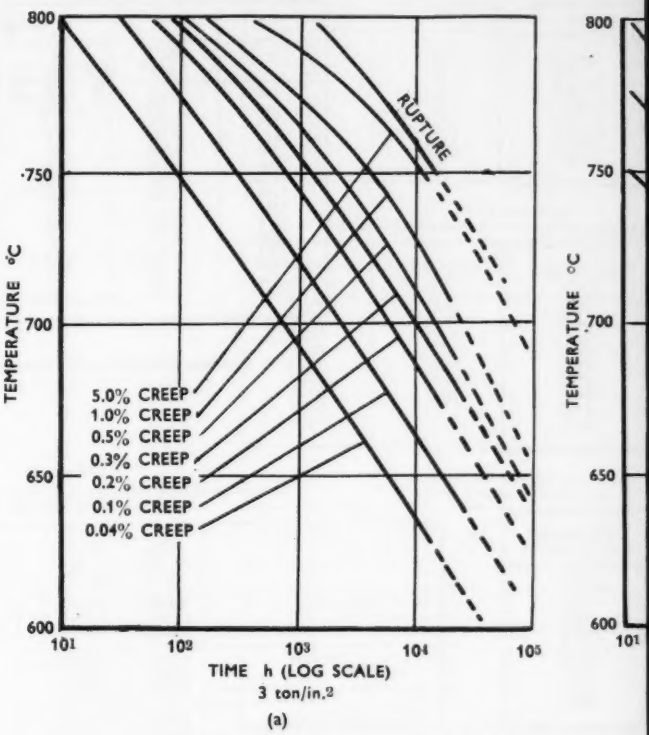
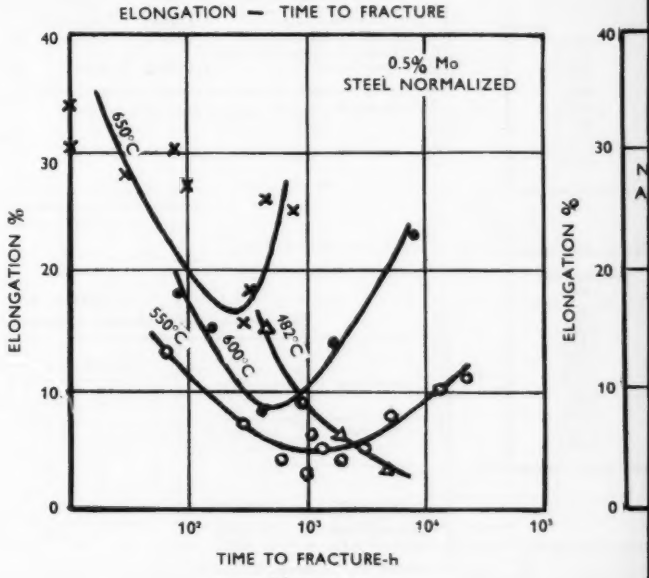


Fig. 2 (c) (below).



(a)

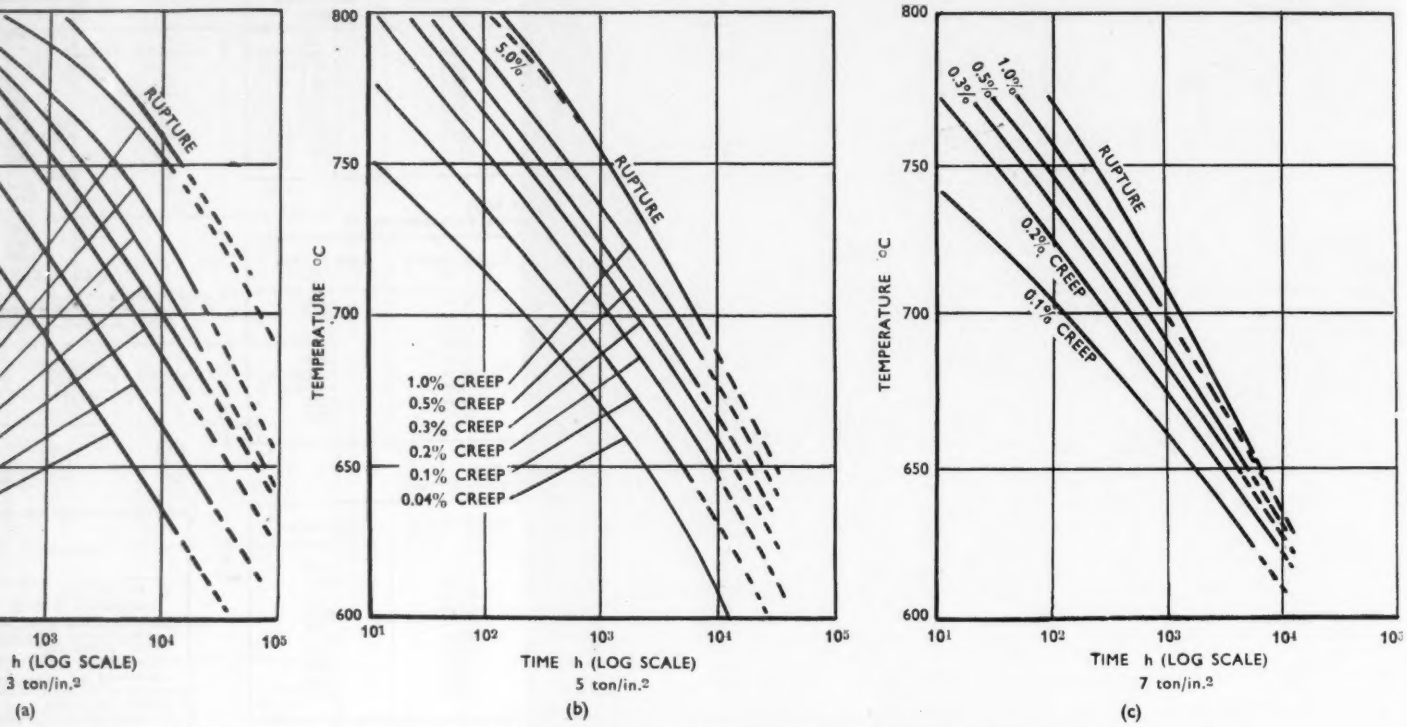
Fig. 3 (a-c) (above).—Temperature-log Time curves for spe
1%



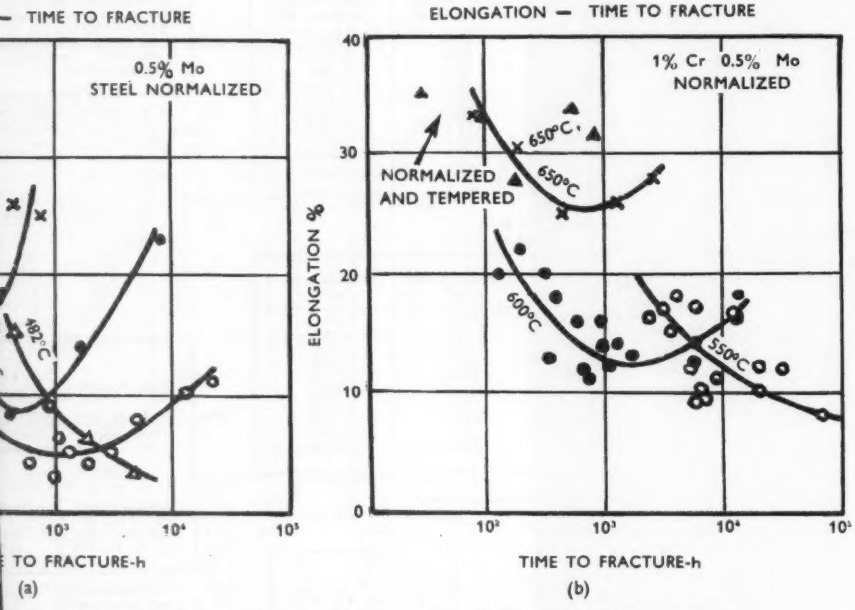
(a)

Fig. 5 (a-b) (above).—Elongations at fracture under creep conditio
which is displaced to lower values and longer times as the tes

Type of steel
1. Plain Carbon
2. 1% Chromium—Molybdenum
3. 2¼% Chromium—Molybdenum
4. Austenitic 18/12/1 Nb type



(above).—Temperature-log Time curves for specific creep strains and rupture. Material : Steam-pipe austenitic steel of the composition 18% Cr, 12% Ni, 1% Nb. Annealed at 1,050°C. A°. (Smith et al. 48.)



.—Elongations at fracture under creep conditions of certain alloy steels showing a minimum ced to lower values and longer times as the test temperature is decreased. (Glen 19.)

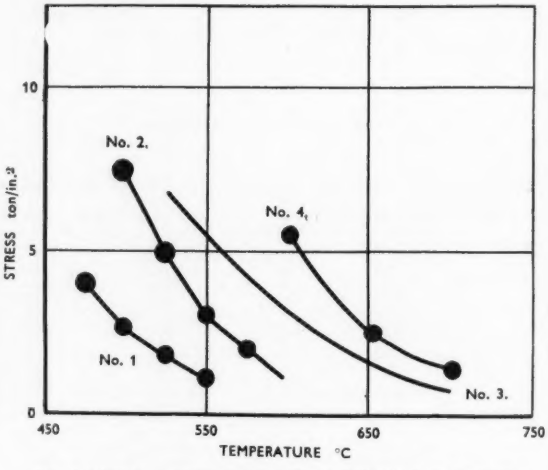
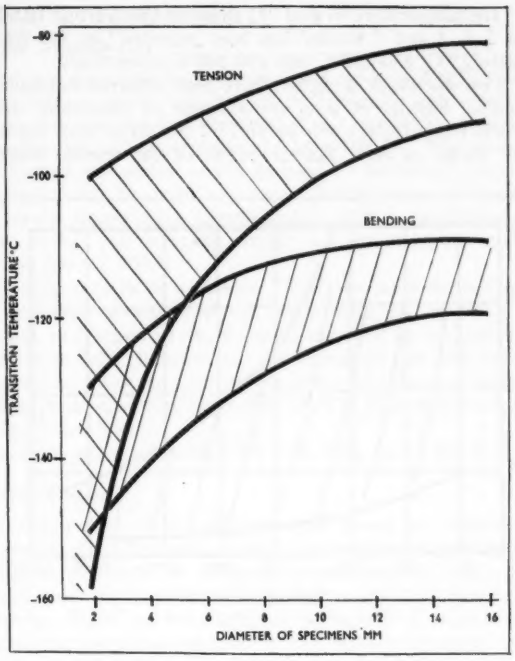


Fig. 4 (above).—Rupture strength in 100,000 h of various pipe and tube steels. For composition of the specimens, see Table D8 below. (Kirkby 45.)

TABLE D8 (See FIG. 4.)

Type of steel	C %	Si %	Mn %	Ni %	Cr %	Mo %	V %	Nb %	Initial heat treatment
1. Plain Carbon	0.12	0.15	0.60	—	—	—	—	—	Normalized at 900°–950°C
2. 1% Chromium—Molybdenum	0.10	0.35	0.60	—	0.80	0.50	—	—	Normalized at 940°C
3. 2¼% Chromium—Molybdenum	0.10	0.35	0.50	—	2.25	1.0	—	—	Annealed at 940°C
4. Austenitic 18/12/1 Nb type	0.10	0.60	1.25	12.0	18.0	—	—	1.0	Air cooled at 1,050°C



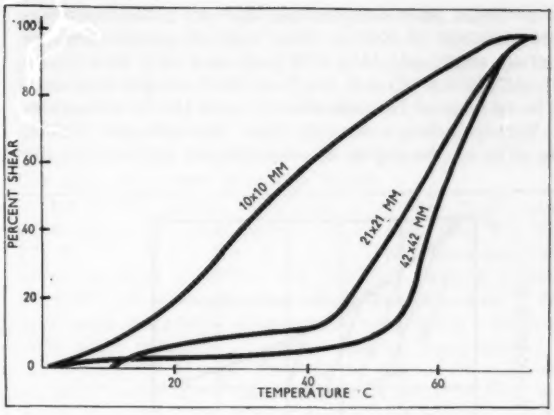


Fig. 3a (left) and b (above).—Showing rise in transition temperature with increase in size of test piece. (a) Un-notched specimen; (b) Charpy Vee notch type of specimen.

show a change in fracture characteristics as the temperature is decreased. However, in alloys with an appreciable ferritic content there is a reduction in impact strength at sub-zero temperatures. The higher ferrite content of weld metal deposits of the stabilized steels show marked changes in impact properties at low temperatures (Fig. 2).

Creep Properties

Ferritic Steels. The steels used in the top domes of existing power-producing reactors are of the mild steel type, either aluminium- or silicon-killed. The aluminium-killed steels have improved notch ductility, but it has been shown[14] that the aluminium additions necessary to cause an improvement in notch ductility give a deterioration in creep strength. Creep data on two carbon manganese steels with varying Al additions have been reported by Sage; the stresses for 0.1% and 0.5% creep in 10^5 h are given in Table 2[15].

Due to the differing deoxidation practices, the superheater material had a finer grain size and this was reflected in the reduced creep strength compared with that of the coarse grained steam pipe material.

Creep data up to 67,000 h on a coarse grained 0.24% C, 0.61% Mn steel have been reported by Ridley[16]. The temperatures for 0.1% and 0.5% creep in 10^5 h at 5 ton/in.^{2} are 443°C and 450°C respectively. This steel has a similar creep stress to the steam pipe material reviewed by Sage[15].

The test results illustrate the superior creep properties of the silicon-killed steels compared with those indicated by the available data for aluminium-killed steels. At a stress of 5 to 7 ton/in.^{2} the upper working temperature to give 0.1% creep in 10^5 h for the aluminium-killed steel is usually defined at 340°C and for the silicon-killed steel at 400°C.

In conventional power plant the demand for higher temperatures has led to the development of alloy steels with improved creep resistance compared with the mild steels already discussed.

The first steel developed for the higher temperatures in conventional plant contained ½% Mo, but due to its relatively poor rupture ductility it has been superseded by the Cr/Mo steels. Two such steels, i.e. 1% Cr ½% Mo and 2¼% C 1% Mo steel are in general use. A comparison of ther relative creep strength of these steels with the coarse grained mild steels is given on the attached Data Sheet (see Table D5), as well as creep design curves on the reverse side of the sheet.

When the elongations at fracture under creep conditions of some alloy steels are plotted against time-to-fracture, a minimum in ductility occurs. As the test temperature is lowered this minimum is displaced to longer times and the value of the minimum elongation at fracture decreases. This effect is most pronounced in the ½% Mo-type of steel although it is also observed to a lesser extent in the Cr/Mo steels of Figs. 5 (a and b)[19] on the Data Sheet. Stress rupture results on carbon manganese steel in the temperature range 400–450°C are limited, but the results quoted in Table 3[20] show that the silicon-killed steels are stronger but less ductile than the aluminium-killed steels. These results confirm the beneficial effect of manganese in increasing the rupture strength.

Fig. 4 on the Data Sheet compares the rupture strength of some of the steels being discussed.

Stainless (austenitic) Steels.—Due to their increased creep

Table 3—Stress Rupture Tests at 450°C in C-Mn Steels[20]

Stress ton/in.^{2}	Si-killed Time to Fracture h	Elongation %	Al-killed Time to Fracture h	Elongation %
0.5%Mn				
14	286	19	142	21
12	3,400	13	680	26
10	6,500	12	2,842	23
1.0%Mn				
14	1,175	28	66	21
12	6,010	34	1,190	46
10	—	—	7,550	35

and corrosion resistance, stainless steels are used at temperatures in excess of 550°C. Two types of composition are generally employed: 18% Cr/8% Ni and 18% Cr/12% Ni with the addition of up to 1% Ti or Nb as carbide stabilizers.

The addition of Nb (columbium) to an 18/8 base increases the high-temperature strength; but American and British data differ in the degree of strengthening imparted by the Nb addition. Keating[3], reporting British data, states that the stress to produce 1% creep in 10,000 h at 590°C is 5.1 ton/in.^{2} for the 18/8 steel and 6.0 ton/in.^{2} for 18/8/Nb steel, while the American source[21] quotes 5.8 and 10.6 ton/in.^{2} for the 18/8 and 18/8/Nb steels respectively. This difference may be due to the different methods of extrapolating creep data.

The temperature to give 1% strain in 18/12/Nb in 10,000 h at 2, 3, 5 and 7 ton/in.^{2} has been reported[22] as 700–760°C, 660–725°C, 630–680°C and 610–640°C respectively.

Low ductilities in rupture have been observed in austenitic steels. Results of tests on a range of chromium nickel steels from 18/10/1 Nb to 18/15/2 Nb have been reported by Bailey *et al.*[23] Scatter bands of the results obtained covering the temperature range 550–750°C are shown in Fig. 4. It can be seen that, in the temperature range 550–650°C there is a tendency for low elongation values at long times-to-fracture. Above 650°C the tendency is reversed to give low elongation values at short times-to-fracture, the elongation increasing progressively with increase of time-to-fracture.

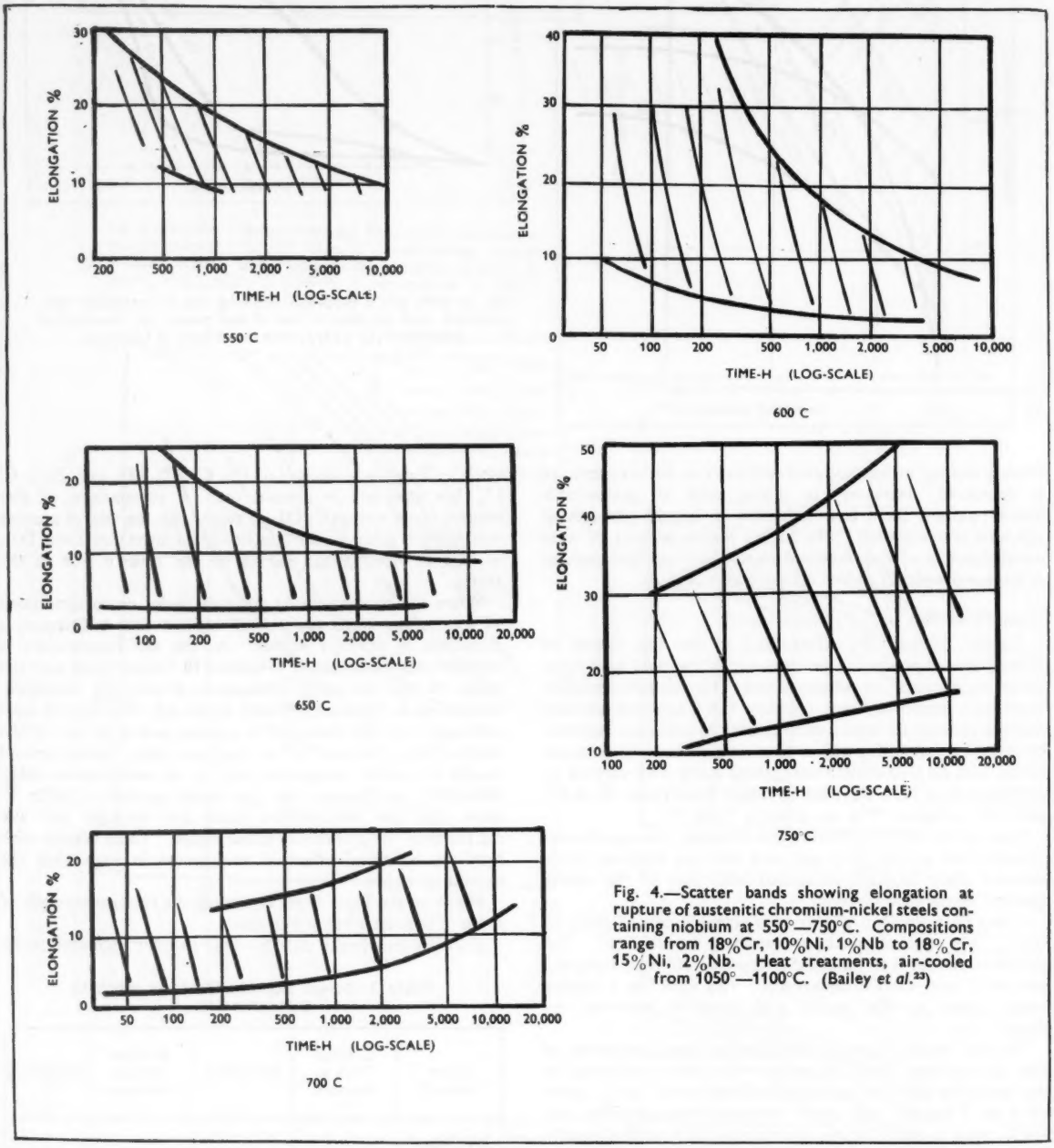


Fig. 4.—Scatter bands showing elongation at rupture of austenitic chromium-nickel steels containing niobium at 550°—750°C. Compositions range from 18%Cr, 10%Ni, 1%Nb to 18%Cr, 15%Ni, 2%Nb. Heat treatments, air-cooled from 1050°—1100°C. (Bailey *et al.*[23])

CHEMICAL COMPATIBILITY

Carbon Dioxide Gas

The rate of attack on pressure vessel steels at 400°C and 8 atmospheres in dry CO_2 falls off parabolically with time[24]; the scaling rate being approximately 1.2 mg/cm²/5 months corresponding to a penetration of 0.16×10^{-3} in. The oxide film formed was adherent and showed no tendency to flake or powder after 5 months' exposure. Extrapolation of these test results would mean approximately 0.02 in. penetration in 20 years. No apparent attack was observed in mild steels at 300° or 200°C.

At temperatures in excess of 550°C the scale formed is non-adherent, severe cracking being observed at 600°C. There is an increased rate of attack, but tests up to 2,000 h duration at 500°C indicate that the change of rate with time is parabolic. Comparison of the rates of attack of mild steels in the temperature range 400–600°C is given in Table C1 on the Data Sheet.

Stainless steels are compatible with CO_2 up to 600°C.

Aqueous Media

In high-purity water stainless steel forms an adherent scale especially if hydrogen is added as a corrosion inhibitor. If oxygen is present in amounts greater than 0.5 ml/l, a heavier oxide scale is formed which can become loose and powdery. Tests[25] on five austenitic steels 18/13/1 to 18/8/1, all show similar corrosion rates in low conductivity water at 280°C and 960 lb/in.². The condition of the surface affects the corrosion rates, pickled surfaces being more resistant than either machined or as-rolled surfaces. The penetration rate in the as-rolled condition falls from an average initial value of about 0.8 micron/month after 7 days to between 0.08 to 0.1 micron/month after 56 days exposure in the liquid phase. Tests on the 18/13/1 steel were extended to 112 days, the observed penetration rates being 0.05 to 0.1 micron/month. Penetration rates for steel exposed to the vapour phase were 50% greater than those for the liquid phase.

The stress corrosion of stainless steels under conditions of chloride contamination is well known, but laboratory tests[25, 26] have shown, even with water of conductivity less than 2 micromhos/cm³, that specimens of 18/13/1 steel, exposed in the vapour phase or at the interface between liquid and vapour phases, exhibited signs of stress corrosion cracking. No cracking was observed in the 18/8/1 steels under these conditions of test. A higher incidence of vapour phase cracking was observed when the specimens were exposed to water containing chloride ions or lithium hydroxide.

The corrosion rates for mild steels are dependent on oxygen level, but if oxygen is entirely removed from the system the corrosion rates fall to low values. These steels do not however form an adherent protective scale. The initial penetration rates recorded after 7 days exposure at 280° and 960 lb/in.² were extremely high, of the order of 15 microns/month in the liquid phase and 8 microns/month in the vapour phase, but after 112 days exposure the overall penetration rates were less than 2 microns/month in the liquid and 1 micron/month in the vapour phase.

Liquid Metal

Stainless steels of the 18/8/1 type have been used in Na/K liquid-metal-cooled circuits and laboratory tests[27] have shown that up to 600°C the weight changes observed were very small; no systematic variations with either temperature or flow velocity were observed. Even though the rate of attack is small, concern has been expressed about the possibility of deposition or concentration of various constituents of the steel which could give rise to gamma-emitting radioactive isotopes in the heat exchangers or cold traps. Concentration of isotopes of a moderate or long half life would cause trouble should servicing of the components be required. Davis and Draycott[27] have shown that the principal active isotopes to be deposited in the heat exchangers are Fe^{59} and Cr^{51} together with small quantities of Co^{60} and Mn^{54}. The extent of the transfer, however, is likely to be such that this does not present a serious hazard.

Due to the relative high cost of stainless steels, some experiments have been carried out on mild steel, ½% Mo, ¼% V; 1% Cr, ½% Mo; 2¼% Cr, 1% Mo steels and other low-alloy steels at 400°C and 550°C in flowing sodium. At 550°C all the steels, apart from the 2¼% Cr 1% Mo steel, were completely decarburized to a depth >0.014 in. Only slight reduction of carbon content was observed in the 2¼% Cr 1% Mo steel towards the edge of the specimen. At 400°C none of the steels tested was decarburized. The results quoted in Table C2 on the Data Sheet show that the weight losses for the 2¼% Cr 1% Mo steel in the normalized and tempered condition are significantly lower than those for the other steels investigated. No accelerated attack was observed on stressed specimens or on specimens which had been spot-welded to simulate the weld heat affected zone. Steel making inclusions are rapidly attacked by liquid sodium and can result in the production of deep fissures. These test results show that below 400°C mild and low alloy steels are satisfactory in sodium, but at 550°C only the 2¼% Cr 1% Mo steel can be considered. If ferritic steels are used in sodium circuits, the steel must be thoroughly cleaned and oxidation prior to service avoided, thereby minimizing oxygen contamination of the liquid metal.

Table 4—Corrosion of 18/13/Nb in boiling 15N Nitric Acid

Concentration of Cr^{VI} or Ce^{IV}	Mean Corrosion Rate over 1,000 h (mg/cm²/month)	
	Cr^{VI}	Ce^{IV}
0.01M	3120	1660
0.001M	1050	665
0.0001M	128	176
0.	32	32

Stainless Steel in Nitric Acid

The corrosion rate of stainless steel in boiling nitric acid[28] is greatly influenced by the presence of certain metallic ions in the solution. Ions which accelerate the corrosion are oxidized members of Redox couples whose standard oxidation potentials E^0 lie between 1.3 and 1.6 V, in particular Cr^{VI}, Ce^{IV}, V^V, and Ru^{VIII}. Table 4 compares the effect of Cr^{VI} and Ce^{IV} on the corrosion rate of 18/13/Nb.

Corrosion experiments with fission product activity in the test solution have shown that radiochemical reactions affect the oxidation reduction equilibrium. This resulted in a reduced rate of corrosion, but under certain conditions the reducing effect of the radiochemical reaction has not counteracted the oxidizing effect of the acid and accelerated corrosion of the steel occurred.

WELDING

The required standard of welding is extremely high and for reactor pressure vessels it is necessary to ensure that when using the proposed techniques, the properties of the weld metal, heat affected zone, and the joint as a whole are not inferior to those of the parent plate.

Low hydrogen electrodes are preferable, to avoid the weld metal and hard zone cracking associated with high hydrogen

Table 5—Effect of Irradiation on the Transition Temperature of Al-killed Steel. Composition: 0.14%C, 0.11%Si, 1.07%Mn, 0.042%S, 0.035%P, 0.103%Cr. 2-in. Plate normalized 920°C. Welds Stress Relieved at 630°C for 4¾ h

		Ductile-Brittle Transition Temperature °C 50% Fibrous Fracture				
		Unirradiated	Irradiated ~ 3.5×10^{19} n/cm² Integrated Flux			
			50—60°C	ΔT°C*	130—140°C	ΔT°C
Parent Plate	Surface	−60 to −70	−42	+23	−28	+37
	Centre	−75	−50	+25	−25	+50
Weld Metal	Centre	−40	−7	+33	+2	+
Heat Affected Zones	Centre	−58	−10	+48	−1	+57

* Change in transition temperature.

content in deposited weld metal, and its subsequent diffusion into the heat affected zone of the parent plate.

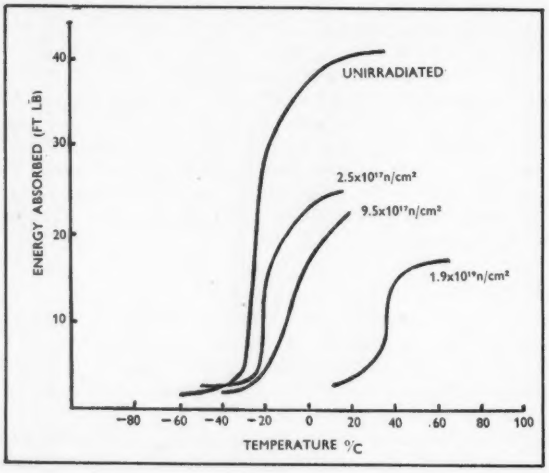
The high heat sink capacity of thick plates leads to extremely severe thermal conditions and it is necessary to pre-heat the plates to a minimum of 100°C before welding. This reduces the cooling rate of the deposited metal and the heat affected zone to a rate, at which under-bead cracking and excessive hardening is avoided, thus minimizing the risk of cracking or fissuring of the deposit under the conditions of severe restraint.

One of the difficulties encountered with thick plates is carbon segregation. Harris[29] has observed carbon segregation up to 0.35% in a 5½ in. plate with cast analysis carbon 0.24%, Mn 1.42%. This segregation caused cracking on welding. The welding techniques used must allow for the segregation to be expected with the type of steel and thickness of plates used.

The importance of establishing and maintaining a suitable minimum pre-heat condition has been demonstrated by several investigators. Vaughan and de Morton[30] working on 1 in. plate, investigated the relation between hydrogen content, cooling rate and weld metal fissuring or cracking. They concluded that a pre-heat temperature of 100°C was necessary to reduce these effects to a minimum. A higher temperature may well be necessary for heavier plate. Investigation on C/Mn and low alloy steels[31] has demonstrated the importance of the cooling rate in the range 250–300°C if cracking is to be avoided. Cracking was observed with rutile electrodes when the cooling rate exceeded 2½°C per sec at 300°C, but the critical cooling rate with low hydrogen electrodes was 12°C per sec.

Further development work[32] led to the establishment of a method of determining the necessary pre-heat temperature by relating the type of joint, the plate thickness and the weldability index, the latter being determined by establishing the critical cooling rate at 300°C by means of a series of controlled thermal severity tests. This work does not take into account the severe restraint encountered in the welding of thick plates, and therefore it can only serve as a guide to the necessary pre-heat.

Fig. 5.—Effect of Irradiation on the Impact Transition of End Steel (grain size 2000 grains/mm²). (Churchman et al.[36])



While data are available on the room temperature properties of weld metal, little is known about the elevated temperature properties particularly stress rupture, and how neutron irradiation affects these properties. These effects can be particularly important in the case of alloy steels when precipitation of complex carbides or nitrides can have a marked effect on properties.

Due to their greater hardenability higher pre-heat temperatures and immediate post-heat are necessary in the welding of Cr/Mo steels.

Stainless Steels. In welding of unstabilized stainless steels grain boundary carbides are precipitated in the heat affected zone with consequent depletion of chromium content adjacent to the $Cr_{23}C_6$ precipitates. The chromium depleted material is rapidly attacked by many electrolytes as it will be anodic to the mass of metal of normal chromium content. This has been overcome by adding Ti or Nb which form stable carbides.

In some of the chemical plant referred to earlier, a fully austenitic steel with a nominal composition of 18% chromium and 13% nickel 0.1% max. carbon, 1.5% max. niobium was used. This type of austenitic steel does not contain any ferrite and difficulties were encountered when electrodes of a similar composition were used. Investigation showed that the micro-fissuring found in fully austenitic deposits and believed to be due to the segregation of impurities at the austenitic grain boundaries as discontinuous intergranular films, could be avoided if the deposit contained a few % of ferrite. The use of an electrode containing a reduced amount of nickel, i.e. 9% instead of the 13% of the parent metal, gave deposits of the requisite 5%–10% ferrite content necessary to avoid these troubles. The actual technique evolved for pipe welding favoured argon arc fusion for the base run using argon backing to control internal bead contour and give a smooth surface, followed by manual arc filling using 18/9/1 electrodes.

NUCLEAR CONSIDERATIONS

The neutron capture cross-section of an alloy largely governs its suitability for canning fuels. However, other considerations such as its compatibility with coolants and fuels, availability, ease of fabrication and strength at high temperatures are often of overriding importance. Austenitic stainless steels are comparatively abundant, easily fabricated and are compatible with coolants and uranium up to 500°C and possibly 600°C. Due to their high temperature strength

properties stainless steels have advantages over the other canning materials, especially if enriched fuel can be used.

When nuclear properties of steels are being considered cobalt becomes an important impurity. This is due to the fact that Co^{60} has a long half life (5.3 years) and is a strong gamma emitter thereby preventing access after irradiation. Where neutron economy is necessary, the high neutron absorption cross-section of cobalt (37.0 barns) is detrimental to its use as a canning material. It follows that it is important to restrict the cobalt content of a steel to as low a value as possible.

Irradiation Damage

Ferritic Steels. Irradiation of mild steels[33, 34] produces an increase in hardness, yield point and ultimate tensile strength with corresponding decrease in ductility, and a rise in transition temperature. The effect of irradiation on tensile properties is given in Table A1[35] on the Data Sheet.

The first effect of irradiation is to lower the energy absorbed in fracturing the specimen[36] without any substantial shift in transition temperature. Greater irradiation dosages, 1.9×10^{19} resulted in a shift in transition temperature of about 100°C, and the maximum energy absorbed is reduced from 40 to 15 ft lb (Fig. 5).

The effect of irradiation in raising the transition temperature appears to be affected by steel quality. Wilson and Billington[35] reporting unpublished work by Berggren, state that the high purity iron and high quality mild steels appear to be less susceptible to irradiation embrittlement than steels with high sulphur and phosphorus content. Trudeau[37] investigating the effects of composition on irradiating alloy ferrites or iron base alloys shows that in some cases (0.5% Mo) the shift in transition temperature and increase in tensile properties is of the same order as the unalloyed ferrite, but in other cases, notably 3.25% Ni, the effects are more marked. Theoretical considerations[38] suggest that the shift in transition temperature is not as great in fine grained steels as it is in coarse grained steels. Tests on fine and coarse A.S.T.M.-type A106 Grade B[39] substantiate this in that the fine grained materials show less shift in transition temperature, although Wilson states that in high purity iron there is no clear superiority of the fine grained metal. Trudeau[37] investigating a complex Ni/Mo/V/Cu alloy steel shows that in the quenched and tempered condition this steel is not as susceptible to irradiation embrittlement as the same steel in the normalized condition. It can be seen that composition and heat treatment can affect the amount of irradiation damage but the effects are not clearly understood.

The available evidence[39, 40] shows that the effects of irradiation on the transition temperature are more marked in the heat affected zone and weld metal samples tested, than in the parent plate (see Table 5).

The effect of irradiation temperature was investigated by Wilson[39] who showed that irradiation at 300°C produced less damage than irradiation at 80°C. This irradiation temperature effect varied with steel composition, but in the case of a 0.2% C 0.82% Mn silicon-killed steel irradiation to 5×10^{18} n/cm² (fast) at 300°C had a similar effect as 1×10^{18} n/cm² at 80°C. Baldwin[41] has also reported that a 0.21% C, 1.25% Mn, 0.5% Mo steel showed no significant change in tensile properties after irradiation at 260 and 370°C to an integrated dose of 10^{19} n.v.t. Annealing in the temperature range 300–425°C tends to restore the material to its unirradiated condition[37, 39, 41, 42].

Translation of the results of available irradiation data in terms of reactor pressure vessel design is not possible at present. Irradiation damage is known to depend on neutron spectrum, temperature of irradiation as well as the total neutron dose, and these must be related to the conditions prevailing at the pressure vessel itself before the quantitative effects can be estimated.

Stainless Steels. Irradiation of stainless steels increases the tensile strength with corresponding reduction in ductility. Changes in tensile properties after irradiation with fast neutrons below 100°C are given in Table A2[24] on the Data Sheet.

Irradiation of a 20% Cr, 10% Ni stainless steel at 100°C[43] caused a slight increase in the ferrite content. Tests were carried out also on cold worked material, the ferrite content rising with increased cold working.

CONCLUSIONS

The trend towards higher gas temperatures will necessitate either the use of alloy steels in pressure vessel construction, or some form of internal cooling or insulation. Even if the shell temperature is kept below the creep range, high tensile low alloy weldable steels are advantageous in that for similar working conditions plates of thinner section can be used. Plates of thinner section simplify the erection problems: the positioning of plates is facilitated, the total weight of the vessel is reduced, the amount of weld metal per unit length of joint is decreased and radiographic or other inspection techniques become simpler and more sensitive. High tensile weldable steels are under development, but to date their use is not warranted for reactor pressure vessels.

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AEA's Fifth Annual Report

Lord Plowden presented his fifth and last AEA report on July 22. He will leave the Authority at the end of the year after 5½ years' service as chairman.

THE Authority's Fifth Annual Report was presented to Parliament on July 22 and on the same day senior representatives of the Authority held a conference to answer questions arising from it. The report covers the period April 1, 1958, to March 31, 1959, and broadly reviews the work of the Authority over the past five years; in the research and development field, which is so wide that a complete picture is impossible, special emphasis is given to the effects of irradiating metals, solid state physics and particle accelerators.

Staff and Finance

The Authority's staff increased over the year from 30,000 to 35,000 but present policy calls for this rate of increase to be halved over the next few years. Expenditure was £105,744,000, plus £80,000 for contributions to international projects; estimates for 1959-60 total £92,433,000, an increased expenditure being more than offset by increased receipts. The operating account of the Authority is withheld from publication in the interests of national security and detailed analysis is therefore impossible. No terms have been published for the royalties to be charged on information made available on the gas-cooled, graphite-moderated reactors, but the statement has been made that Bradwell, Berkeley and Hunterston will pay no such royalty although all subsequent stations are so required.

The report contains a warning to uranium producers of overproduction and a limited market. A price lower than the current $8/lb is anticipated which should in time be reflected in the charges made for fuel elements. Stocks of beryl ore are considered adequate and in consequence purchases have been reduced.

Fuel Element Production

In January Springfields produced its millionth fuel element and new production plant was brought into operation. A fabrication plant is under construction aimed at satisfying all home and export demands for natural and enriched uranium and uranium oxide elements. For reprocessing, a new separation plant is to be built at Windscale based on an improved separation system with the integration of all solvent extraction stages into a continuous process. The extensive use of salt-free stages will allow evaporation of all fission product streams so that major effluent will be relatively inactive distillate. The new plant also includes a nitric acid recovery plant. A weld failure in October, 1958, in one of the highly active dissolver cells caused this section of the original plant to be shut down and, following decontamination, a new solvent extraction process was incorporated.

Isotope Production

Closing of the Windscale reactors restricted production of long-lived isotopes particularly carbon-14 and cobalt-60. Some 300,000 curies of cobalt-60 have been produced in the Calder Hall reactors providing material for two large-scale irradiation facilities, one at Wantage and the other for the sterilization of animal fibres against anthrax at a commercial installation in Australia. The experimental separation plant for caesium-137 and strontium-90 has been closed down after producing 1,400 curies of caesium.

Power Reactor Projects

Confidence is expressed in the ultimate applicability of beryllium for fuel cans although the first enriched commercial power stations are likely to use stainless steel. Extensive tests have been made on the element clusters, particularly to determine optimum heat transfer and coolant flow characteristics. Substantial improvements in heat transfer can be obtained by roughening the surfaces of the fuel elements.

No choice has yet been made for a second string to the AGR although steam-cooling heavy-water moderation is believed to hold considerable promise. No decision has yet been made to build a prototype although work has begun on the design study for a 100 MW (H) SCHR to be operating by the end of 1962. Common services would be provided in such a plant for a second reactor and should a BWR project be initiated a prototype could be built alongside. The high enrichment necessary for this plant (1½%) even with zirconium cladding is still considered excessive with British fuel prices.

Fast Reactor

Confidence is also returning in the fast reactor and DFR is due to go critical shortly. It will be run up to 1 MW by the end of the year and up to 12-15 MW by next summer. Extensive collaboration with the Americans on fast reactor technology has been initiated.

Investigations into the breakdown of organics when used as moderators are continuing and present estimates show that replacement costs in a typical power station employing organic moderation and cooling would be 1/10 d/kWh. No detail of work on this reactor project is included in this report.

Research Reactors

Studies have continued with the research facilities NERO, DIMPLE, NEPTUNE and LIDO at Harwell but ZEPHYR has been dismantled and HAZEL is to be taken down and reassembled at Dounreay for general studies of criticality problems in chemical plants. A light-water moderated system EUREKA (*Nuclear Engineering*, March, 1959, p. 102) is virtually complete and a programme to study the physics of light-water moderated systems is in hand. At AWRE, HORACE is providing data for the rapid run-up of the MERLIN-type reactor, HERALD, due to go critical shortly.

CTR Work

Thermonuclear research has shown considerable discrepancies between experimental practice and theoretical predictions. It has been found that the electron energy in the ZETA discharge is considerably less than the ion energy, the relative temperatures being approximately 500,000 and 5,000,000°C. It has also been found that the current flows through the volume of the channel rather in the skin which would lead to considerable instabilities in the plasma. The mechanism of the major energy loss is however not yet understood and a new machine, ICSE (Intermediate Current Stability Experiment), is to be built. This will be a fast pinch (as against the slow pinch ZETA) toroidal machine fed from a condenser bank of 5-10 MJ capacity. In the meantime work on ZETA II will be slowed down to await results on ICSE which will allow detailed study on the various mechanisms of energy loss. The provision of complex magnetic fields giving a reversed field within the plasma is expected to increase the stability of the discharge. At AWRE work continues on high-speed discharges in linear tubes and a small project has been instituted centred around a proposed device called HITEX (High Temperature Experiment) which is an injection machine similar to the Oak Ridge DCX device. Great attention is also being paid at AWRE to the development of diagnostic apparatus.

Research at Aldermaston

THE Nuclear Physics Research Division of AWRE, Aldermaston, opened its laboratories for inspection on June 2. The Division was formed in 1955 primarily for the purpose of obtaining certain technical data required for the Weapons Project, but a considerable part of the work carried out in the Division is of interest to the nuclear physicist generally and will be made available through the normal channels of publication. The Division has four accelerators —an 800-kV Cockroft-Walton machine and three Van de Graaff-type electrostatic generators, of 3 MeV, 6 MeV and 12 MeV respectively. The last-mentioned type is of the Tandem variety and although its construction bears some similarity to the machine developed by High Voltage Corporation, U.S.A., it is an entirely British development and was designed in collaboration with AERE, Harwell, and "engineered" jointly with Metropolitan-Vickers Electrical Co., Ltd.

The generator is in a vertical position and housed in a building nearly 100 ft high. The cost of erection and construction was about £200,000. Doubling of the energy from 6 MeV to 12 MeV considerably widens the scope of the experiments including now the examination of heavy nuclei, such as uranium.

Recent investigations employing a large cadmium-loaded liquid scintillation counter, viewed by eight 5-in. photomultiplier tubes, have established that $\bar{\nu}$, the number of neutrons emitted in the slow neutron fisson of U-235, is about 6½% lower than the currently accepted "world best value," viz, 2.326 ±0.053 as against 2.46. This is an important result as it goes a long way towards explaining why hitherto in critical-size determinations the theoretical values obtained were smaller than those arrived at empirically.

Other experiments, conducted at AWRE in conjunction with Van de Graaff accelerators and involving highly sensitive, specially developed instrumentation, are concerned with the measurement of neutron energy spectra. The energy of a neutron can be determined directly by measuring the speed with a time-of-flight spectrometer. A "chopped" neutron beam emitted from a target is directed on to the material of interest situated near. Oscillating the primary beam of deuterons over an aperture results in a burst of neutrons of 5 mμsec which strike the irradiated nucleus every 200 mμsec. Assuming that the neutron source is a tritium target which will produce neutrons of 14 MeV and that the nucleus will emit neutrons of 4, 2 and 1 MeV under bombardment, then a counter placed (say) 1 m from the nucleus will record pulses at 3.3 mμsec after each burst (corresponding to gamma rays from the source), at 19.3 mμsec (corresponding to neutrons reaching the counter direct from the source) and at 46.1, 51 and 72.3 mμsec respectively representing the degraded neutrons originating from the nucleus. The energies would thus be determinable from the temporal distribution of the pulses.

A considerable amount of work at AWRE is devoted to subjects of immediate significance to the power field, such as the technology of plutonium and beryllium. Fuel elements comprising aluminium-clad, 20% plutonium alloy have been developed which are undergoing preliminary tests in GLEEP and subsequently will be studied methodically in DIDO. Improved methods of casting, machining and welding beryllium have been evolved.

Speaking in general terms, Sir William Penney, who as the member of the Authority for research and past director of the Weapon's Group conducted proceedings on that occasion, estimated that approximately 10% of the Establishment's effort is spent on problems essentially of interest to peaceful applications.

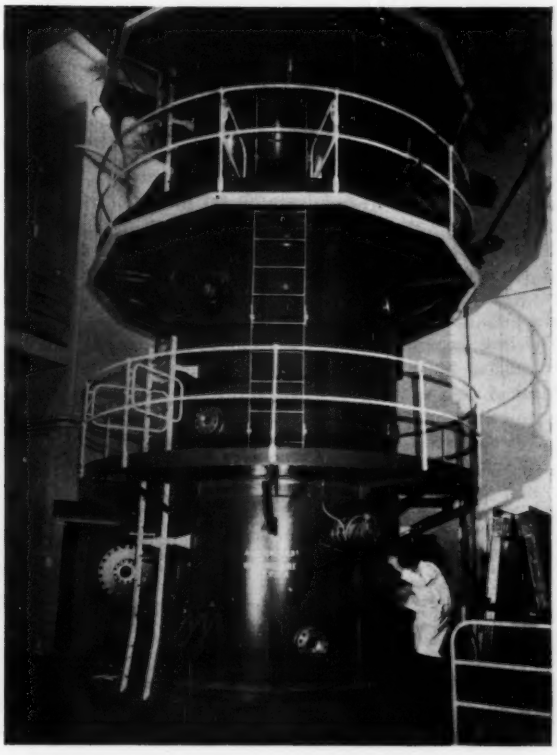
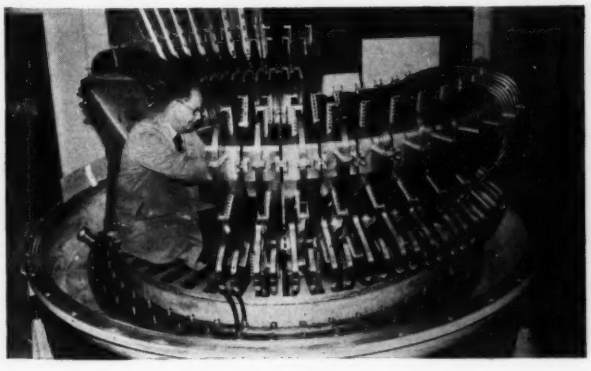


Fig. 1.—(Right) A general view of part of the 45-ft high-pressure vessel containing the 12 MeV Van de Graaff-type Tandem electrostatic accelerator, recently completed at AWRE.

Fig. 2.—(Below) Assembly of the multi-channel spectrograph to be used in conjunction with the 12 MeV electrostatic accelerator for the determination of the energy spectra of charged particles originating during a nuclear event.



FUEL FABRICATION FACILITY

The Argonne National Laboratory have established a Fuel Fabrication Facility for the limited production of plutonium fuel elements for experimental purposes.

AFTER more than three years' design work by staff members of the Argonne National Laboratory, and a period of construction lasting two years, the Fuel Fabrication Facility was dedicated on May 14. Costing $4,000,000, the facility, which is located at the AEC's Argonne Laboratory in Lemont, has been designed to cater for general development and research on plutonium handling and for fabricating plutonium fuel elements.

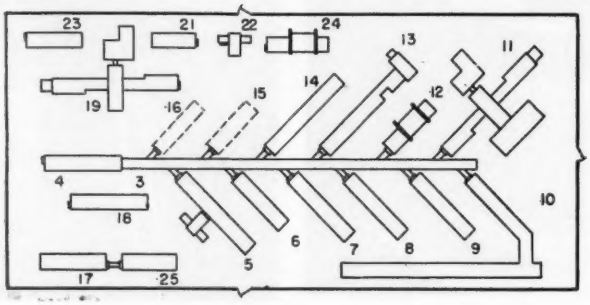
Plans have been made for the inclusion of these elements in the Experimental Breeder Reactors 1 and 2 and the experimental boiling water reactor, EBWR. Fuel plates are also to be fabricated for the Zero Power Reactor 3. The first experimental test assemblies are expected to be completed by the autumn of 1960. These will be for the Mark 4 core loading of EBR-1.

Built to fill the multiple roles of a fabrication process development laboratory, pilot plant, and a facility for the limited production of plutonium fuel elements, the Facility is equipped with an array of machinery of flexible size, variety and capacity in order to meet with a wide range of demands needed to cope with a developing technology.

The plant is housed in one building 245 x 72 ft with a single room 165 x 72 ft, unobstructed by columns, for the fuel production. All floors, in sections where there is a risk of radioactive contamination, have been covered with built-up fibreglass and polyester coating.

The building has been split into three sections; administration, technical and fabrication, with each section sealed from the others but having access by means of air locks. The technical area serves mainly as a store-house for

3—Conveyor
4—Introduction and removal
5—Machine shop
6—Electrolysis and aqueous solution
7—Weighing and inspection
8—Centrifugal casting
9—Ingot casting
10—Extrusion press
11—Rolling mill A
12—Plate shear
13—Wire fabrication



14—Press work
15—Future line
16—Future line
17—Welding and cladding
18—Decontamination
19—Rolling mill B
21—Work bench
22—Milling machine
23—Lathe
24—Plate shear
25—Liquid metal filling

The far end of the fabrication line looking towards the entrance. The five glove box lines, starting bottom centre to left rear are: two casting lines; weighing and inspection line; machine shop line; and liquid metal line.

radioactive materials, equipment, clothing, etc. Reinforced concrete floors and roof decks have been used throughout; the building and floor portions in the fabrication section have been built to withstand loading of 300 lb/ft^2.

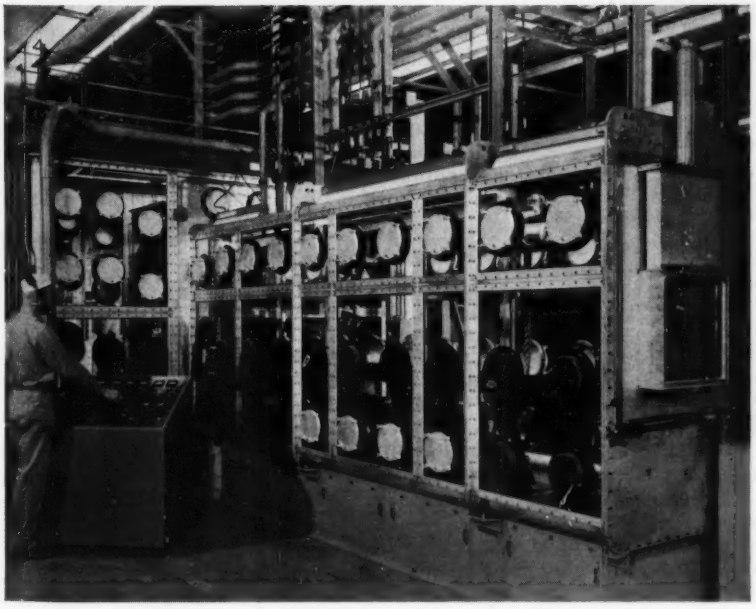
Ventilation is by separate air conditioning systems to each section with safeguards to prevent radioactive dust from spreading between areas. About a half of the building is below ground level.

A herringbone pattern (see plan) was chosen for the production line with a series of integrated glove boxes branching out from each other. The transitions and operating glove box lines were laid out with their longitudinal axes at 135° from the axis of the conveyor line allowing the transfer of pieces 6 to 8 ft long into a conveyor enclosure only 30 in. wide. The central conveyor line (3), contains a single shuttle car riding on rails which enclose a continuous roller chain drive moving on sprocket wheels. It is controlled by a series of push buttons at each operating glove box line and non-radioactive and sealed materials are introduced through a system of locks at one end while contaminated materials are removed, without exposure to room air, by a plastic pouch transfer technique.

The glove boxes were designed with a view to housing small delicate inspection equipment as well as large equipment such as rolling mills, and allow for pieces of equipment up to 42 in. in width and then provide complete access from both sides within the radius of the gloved arm of the operators. The boxes have all been gasketed together to prevent air leakage and have heavy aluminium floor plates and rigid hood frames. Separator plates provided between the ends of the modules have been extended above and within the box structure to support the structures above and within. The gasket system makes use of O-rings and allows for metal to metal bolting of the box flanges. Windows are of cast allyl plastic. In all, 106 boxes, ranging in size from 18 to 800 cu. ft have been incorporated; the sealing doors which separate them from the conveyor are similar to 19-in. double disc gate valves.

A helium atmosphere was chosen for the process enclosures in order to minimize the risk of fire and oxidation and to permit the processing of materials that are pyrophoric in air. Additional to its inertness, helium possesses a number of characteristics which make it especially useful in a plutonium experimental facility. It has a high heat capacity and excellent heat transfer properties, it may be purified by regenerative physical means and techniques are available for determining leaks. The system consists of two circuits, one circulating 1,000 to 2,000 cu. ft/min of gas through the boxes and the other a regenerative purifying circuit handling approximately 100 cu. ft/min. Total capacity of the circuit is 10,000 cu. ft. Care has been taken to minimize leakage but loss is estimated at 300 to 400 cu. ft per week of operation, depending partly on the number of times objects are put in or taken out.

A water cooling system is provided



The rolling mill line B, being operated from a remote control station. A second operator is located on the other side of the glove boxes.

throughout, for use in the various processes, and maintained at a negative pressure because with gas-tight hooded-enclosures, leakage of a conventional positive pressure water cooling system would result in flooding of the hoods with the attendant risk of a critical accident, chemical explosion and spread of contamination. The cooling water is pumped, or sucked, at sub-atmospheric pressure by a water jet produced by two turbines which supply the actuating liquid at approximately 100 lb/in.^{2} pressure drop across two eductors. These eductors each entrain nearly 13 gal/min of water at 70°F and at a suction lift of 20 in. Hg. The recirculated water is then passed through a packaged cooler capable of removing 250,000 B.t.u./h from the coolant. Entrained gases are vented to a filtered air exhaust system.

Fabrication Equipment

In the centrifugal casting line (8) are two vertical spindle rotary table and vacuum centrifugal casting machines, capable of melting 10 kilograms of plutonium alloy at a vacuum of 0.0001 mm Hg and casting alloy under centrifugal forces up to 80 G in multiple permanent moulds. Diffusion pumps are used in all high vacuum systems.

The ingot casting line (9) includes a furnace consisting of a bell jar type vacuum chamber fitted with induction equipment capable of melting up to 10 kilograms of alloy under a vacuum of 0.0001 mm Hg and casting it into water-cooled copper moulds. Small diameter rods are injection cast in precision silica glass moulds and coated with a refractory material in dual zone vacuum pressure furnaces. Up to 130 moulds, closed at the upper end are suspended above the melting crucible which is heated by induction and mounted on a vertically acting ram. A pair of thermal shield doors separate the melting zone from the mould heating zone. The furnace is evacuated by a diffusion pumping system to less than 0.0001 mm Hg and the moulds are brought to temperature (approximately 400°C) and the fuel alloy melted under vacuum. Then the crucible is lifted to immerse the open ends of the moulds. A three-way vacuum pressure valve is operated closing the vacuum pumping system from the furnace and opening a line to a pressure accumulator after a slight delay which allows quieting of the metal. This pressure change then causes the metal to fill the mould tubes where it freezes. The moulds are removed from the furnace after cooling and the castings are stripped away, cut to lengths and inspected.

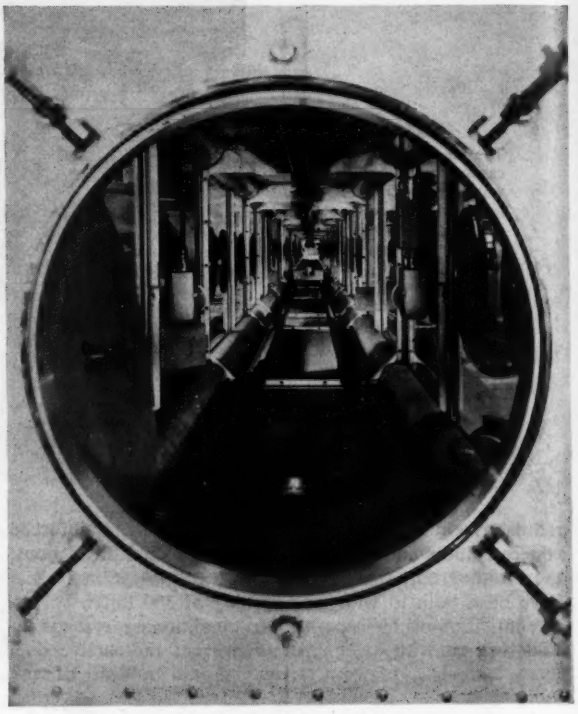
Rolling Mill

On the rolling mill line (11) equipment is of standard design but the plate shear line has a specially designed ½ in. x 6 ft capacity shear plate with the end frames of the shear acting as dividing frames between the process boxes. This has been found necessary in order to keep the working parts of the shear within reach of the operator's arms.

Incorporated in the pressing and powder working line (14) is a 250 tonne down-acting, four column press which has been designed to allow hooding to the lower platen and upper strain head by means of neoprene rubber compression packings. Other protection methods against radiation have also been included.

Provision has also been made along the central conveyor for future box lines (15 and 16) and all services were extended to capped valves for these lines with transition enclosures and transfer platforms provided with sealing doors and blank-off plates.

The welding, jacketing and bonding lines (17) will be used not only for the direct handling of alpha radioactive materials but also for handling non-contaminated materials. Equipment in these hoods is kept constantly



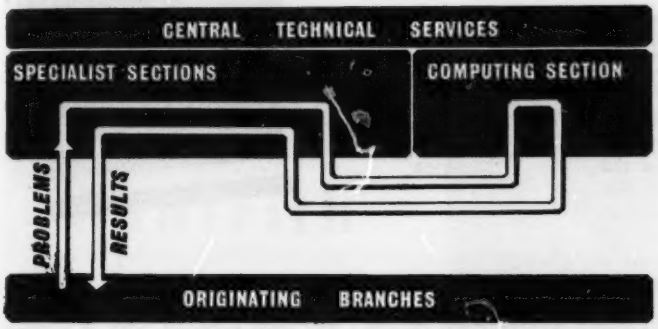
This is a view of the conveyor line through a cast allyl plastics window. On the immediate left and right of the entrance are the photoelectric cells which comprise part of the conveyor interlock safety system.

free from radioactivity so that clean jacketing surfaces do not become contaminated and to avoid possible transfer of contamination through the conveyor. The boxes are not attached to the conveyor system. In this line the swivel mounted clamping press consists of a structural steel frame holding four pneumatic cylinders operating a common water-cooled platen. The frame is carried upon swivels which allow rotation of the press through a 210° arc and the assembly is mounted on a carriage, power driven and mounted on tracks beneath a welding torch holder. This may be moved up and down and across the direction of the press movement, providing free motion between the clamping press and the welding head as well as providing rotation of the work, which is clamped in a horizontal position. The press is swivelled 90° so that welding may be done and the assembly can then be rotated 180°.

Metal Bonding Line

Equipment in the liquid metal bonding line (25) includes a vacuum-pressure turret apparatus for filling spaces between the fuel rods and their metal containers with liquid sodium potassium alloys and for plugging and welding shut the fill openings, a small screw press for sodium extrusion, a vertical tube furnace for removing gas and bonding and gas purifying apparatus and a high vacuum pumping system.

A blast cleaning machine is accompanied on the decontamination box line (18) with electrolysis equipment and vapour degreaser. This line is air ventilated with the air being exhausted through an alkali air washer located in the basement.



Computing for Industrial Nuclear Energy

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(U.K.AEA Research and Development Branch, D. and E. Group, Risley)

RAPID growth of automatic computation over the past 10 years raises the question whether this growth has outstripped that of requirements for it, or whether it is merely catching up with a long-felt need. Is computational work, in fact, merely expanding to occupy the facilities now becoming available, as Professor Parkinson might suggest? Or are these facilities justifiable on economic grounds?

The answer to this question depends very much on circumstances. If, for instance, a product is quickly and cheaply made, its development is probably most economically carried out by means of trial and error on the finished article. If the product is expensive and its design data scanty, but if, nevertheless, the necessary experiments are relatively cheap, an experimental approach would be favoured. Under such conditions, however, an experiment would not necessarily be more reliable than a calculation and would, therefore, be accompanied by fairly simple theoretical checks.

When, however, to the expense of the product and the paucity of the design data is added a high cost of any experiment, the situation arises in which more elaborate calculations are justified; not only to discover the salient features of the problem, so that the most useful information can be derived from a limited amount of experimental work, but also to interpolate, as exactly as possible, from the few experimental results obtained. It is just this last situation which so frequently faces the nuclear industry, and it is hardly surprising, therefore, that in this industry the computing requirements should have become so urgent.

The Need for Computers

That similar situations may have faced other industries in the past, before present-day computing techniques were available, is no argument for not making use of these techniques now. It is rather an indication that some worthwhile developments or design possibilities in those industries were missed, or that they were only discovered after a greater expenditure of time and money. In an age when this handicap was shared by all competitors in a particular field, its effects were not very serious, but today, when the same experience can be economically avoided by automatic computing, its consequences could be grave.

Nowhere do these arguments apply with greater force than to the D. and E. Group of the U.K.AEA, committed as it is to the development, design and construction of prototype nuclear power reactors, also chemical and other plant. To these commitments must also be added its rôle as consultant to private industry and the generating boards.

Development and Engineering Group Organization

In order to carry out its different duties, the D. and E. Group is organized into a number of branches, most of which demand support in the theoretical and computing field. This support is provided by the R. and D. Branch in the form of its Central Technical Services at Risley, which include not only a rapidly growing computing section but also a number of specialist sections, covering subjects such as neutronics, fluid mechanics and stress analysis. These specialist sections can accept a problem in the form of physics or engineering, convert it into a mathematical form and then, if necessary, pass it to the computing section. The results are passed back from the computing to the specialist sections for presentation to the originating branch in a readily digestible form.

For some years the former Industrial Group relied upon the use of a large number of electric desk calculators for numerical computing. There are disadvantages in this system in that the time required to set up numbers on the keyboard or to transfer a calculated result to paper is appreciable and irreducible. Furthermore, the time required to decide and check what is the next step in the calculation is limited by the mental agility of the operator. It will also be clear that when a calculation has to be repeated for a large number of different data, the same chance of error arises with each repetition.

A great step forward from this position was taken with the introduction of the electronic digital computer. In this machine electronic means are employed to record

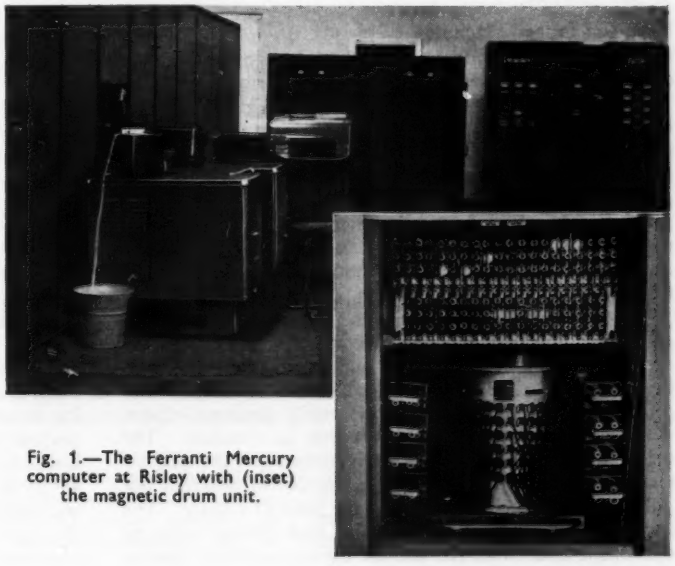


Fig. 1.—The Ferranti Mercury computer at Risley with (inset) the magnetic drum unit.

instructions and numerical data in a storage system and to transfer them to and from an arithmetical unit. In this way, the storage system replaces the desk computers' work sheet and the arithmetical unit the desk calculator itself, the various operations being performed with extreme rapidity. Just as in the case of desk calculations, a programme of instructions must first be drawn up for the machine to obey and little time can be saved on this part of the process. Once the programme has been prepared and thoroughly checked, however, results can be obtained from it for a wide range of input data in a fraction of the time that desk calculation would require and with a far more certain guarantee of accuracy. This feature of digital computation is particularly valuable when a calculation has to be repeated a large number of times, either to cover all possible variants in the design parameters of a plant or to allow for wide margins of uncertainty in the basic data.

Digital Computers

As a start towards realizing the advantages of automatic digital computation, use was first made of the Mk. I machine at Manchester University. A team within the Computing Section was trained to programme for this machine and time was used on it to an increasing extent until Manchester University installed their Mercury computer. New work was thereafter programmed for the Mercury whilst Mk. I was still used for programmes already written. With the gradual realization of the advantages of automatic digital computation throughout the former Industrial Group, demand for time on the Manchester Mercury had grown at an ever-increasing rate to use up all the time that could be allocated. Recently, a Ferranti Mercury computer has been installed in the Computing Section and all digital computing work hitherto performed at Manchester has now been taken over directly by this machine.

This machine as now installed is shown in an accompanying illustration. It is a floating point binary machine with magnetic core high-speed store and magnetic drum backing storage. The high-speed store can accommodate up to 1,024 words of 40 binary digits each, whilst the backing store can hold 16,384 such words. Input and output is by punched paper tape. The machine has an addition time of 180 microsec and a multiplication time of 300 microsec.

Need for Larger Machines

Although the Mercury machine is capable of meeting the day-to-day requirements of the various branches of the D. and E. Group, other problems require digital computation that is quite outside the capacity of the Mercury. Items like control rods causing non-uniformities in the distribution of the neutron flux in a reactor call for the determination not only of the flux itself, but of the temperatures of fuel, coolant and moderator at a large number of points in the core, so that a machine with a storage capacity of 100,000 words or more is required. Again, transmission of neutrons through a material is frequently calculated from their assumed bulk behaviour in groups, each extending over a wide range of neutron energy. To ensure that a process plant is sufficiently removed from the possibility of becoming critical, however, more precise calculations are required if unnecessarily large and therewith expensive factors of safety are to be avoided. The required degree of precision is furnished by the Monte-Carlo technique, in which a large number of neutrons are individually tracked by applying the laws of chance. The accuracy of the result obtained is then limited only by that of the data employed and the digital computer appears as an extremely flexible and comparatively inexpensive experimental facility. For such purposes, also, it is clear that a machine of very large storage capacity is required.

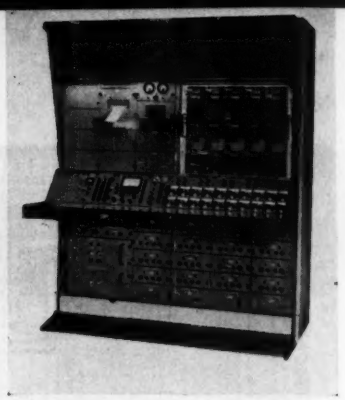


Fig. 2.—EAI's Pace analogue computer Type 231R.

A digital computer which meets this requirement is the IBM 704, one of which is installed at the A.W.R.E. Aldermaston. This machine has a high-speed store, which can hold 32,768 words, and a magnetic tape backing store which can hold some 10 million words. It is to be transferred in the near future to the Computing Section at Risley.

Analogue Computers

Despite the undoubted advantages of the automatic digital computer, there is a range of problems for which the analogue computer is more suitable. In view of the fact that differentiation can be effected by a single element of an analogue computer, and that the variation of a number of dependent variables can be displayed against one independent variable on cathode ray oscilloscopes, it follows that the type of problem most suited to an analogue computer is one which can be formulated as a series of simultaneous ordinary differential equations. Although less accurate than the digital machine, the analogue computer enables the conditions of the problem to be varied whilst the results are being viewed. This feature of the analogue computer is especially valuable when the next condition to be investigated depends strongly on the results obtained from the previous one. In such a case the analogue computer can obtain results for a large number of conditions in a much shorter time than would a digital.

It is precisely this type of problem that arises in studying the transient behaviour of nuclear power reactors. This behaviour is mathematically formulated as a series of simultaneous time-dependent ordinary differential equations. The problems cover the response of the reactors to various fault conditions and to the method of start-up. Problems of control particularly call for a large amount of analogue computer work.

In order to meet their commitments in the analogue computer field, the Computing Section has installed a PACE analogue computer from Electronic Associates Incorporated of America. It is the largest analogue computer commercially available, having 60 integrating amplifiers and 90 summing amplifiers in addition.

As computing facilities have developed within the Computing Section, so it has been found that demands for computational work have come in at an ever-increasing rate. At the moment, this rate shows no sign of slackening and the saturation point of both the facilities available and those on order can already be clearly foreseen. This trend is clearly in line with the one referred to in the opening paragraph and stems from the special position that the nuclear industry holds. In fact, the growth of numerical computation within this industry is all the more to be welcomed in the light of the current shortage of qualified technologists. It is logical to suppose that the pressure of the demand for computational work must eventually approach a limit, but the time for this is clearly not yet.

Atomic Energy Establishment, Winfrith

The 700-acre site in Dorset is rapidly taking shape as a power reactor development centre. Work began on the site less than two years ago.

THE AEA's new Atomic Energy Establishment at Winfrith, Dorset, is rapidly nearing completion and various buildings are already in use. In less than two years some 700 acres of partially inundated Dorset peat bog has been transformed into a broadly designed, self-contained centre intended specifically for power reactor development. Mr. D. W. Fry is the director-designate of the establishment. Winfrith will also accommodate an OEEC detachment working on the DRAGON high temperature, gas-cooled project with Mr. C. A. Rennie as chief executive. In September the team of physicists, mathematicians and engineers concerned with gas-cooled, graphite moderated power reactor design at Harwell will move to Winfrith. Later in the year, the Harwell personnel investigating other reactor systems—light and heavy water, boiling water, steam cooled and organic moderated will follow.

Top view of ZENITH taken through the shielding doors.

Winfrith is conspicuous for the orderly and attractive appearance of the site. The Authority's design staff and the main contractors for this work, Turriff Construction Corporation, have obviously worked closely with the Dorsetshire County Council to produce a series of buildings that are sensibly functional and at the same time harmonize with the surrounding area.

ZENITH

The most interesting development at Winfrith so far is the construction of ZENITH, a zero energy reactor, which is being built by G.E.C. for high temperature research. Commissioning tests will start in a few weeks and the reactor will go critical later this year.

Associated with ZENITH is an exponential experiment for studying fuel elements. The elements comprise discs of thoria and urania, interspersed with graphite in an impermeable graphite tube, and a team is assessing the effect of varying arrangements of the discs.

Computing Facilities

Winfrith will have its own computing facilities; a PACE analogue machine is already in operation. The unit is particularly well adapted for solving problems relating to reactor kinetics because equations can be set up on a patch panel. The installation at Winfrith also has digital input facilities and output plotting devices. A mercury digital computer is on order.

ZENITH will be the first reactor to go into operation at Winfrith and the site is planned to accommodate another five experimental reactor projects. In addition, laboratory facilities will be available for handling irradiated material. Because of the possibility of contamination an extensive effluent disposal system is being established. Surface water and a small amount of purified sewage effluent will be discharged to local rivers. All other wastes will be treated and discharged to the sea. Depending on the activity level the liquid will be pumped to one of three 200,000 gallon disposal tanks for final analysis or diverted to a chemical treatment plant. Non-radioactive effluent is passed direct to two 200,000 gallon tanks. Both types of effluent are subsequently piped to the sea. The pipeline system comprises a pipe within a pipe, radioactive waste flowing through the inner pipe and inactive effluent through the outer annulus. The pipeline is cathodically protected and monitored.

Effluent Pipeline

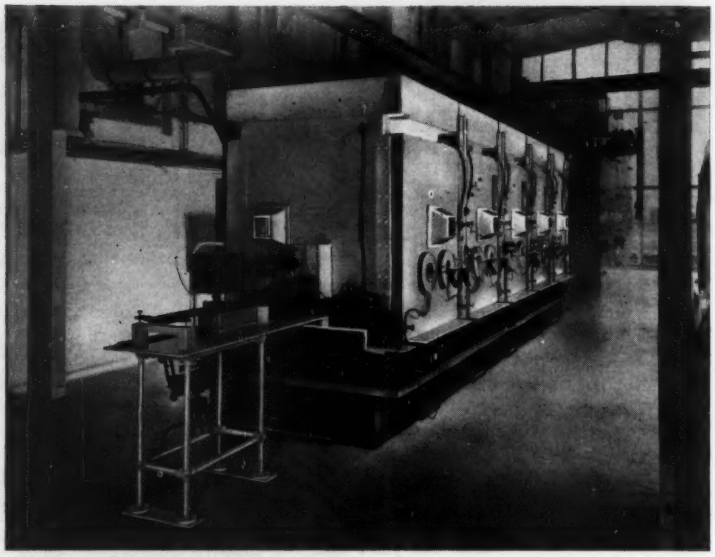
Following an extensive programme of research into the dilution and dispersion of effluent last year, it was decided to discharge the radioactive effluent two nautical miles south of Arish Mell on the Dorset coast. This latter piping is partially welded up on shore and then towed out to sea. The piping system is being built by two contractors, the overland portion by John Brown and the portion projecting beyond the coast by Taylor Woodrow.

Third Generation

It would appear that AEA Winfrith will be concentrating initially on studies connected with the high-temperature, gas-cooled power reactor which are expected to form the basis of the third generation of U.K. nuclear power stations. In due course, however, the establishment will pay close attention to other systems as well. Some of these studies may lead to the construction of experimental reactors on the site.

Fuel Element Examination Laboratories

The first commercial laboratory in the U.K. for the complete examination of radio-active materials has been built by a member of the A.E.I.-John Thompson group.



METROPOLITAN-VICKERS ELECTRICAL have built a laboratory at Wythenshawe for the study of radio-active materials. Costing £200,000, the laboratory consists of two large caves and five smaller interconnected cells. It will be used for the examination and testing of irradiated components and materials ranging up to a complete fuel element and having an activity of 10 kilocuries.

Work will be done both for the A.E.I.-John Thompson group, of which Metropolitan-Vickers are members, and also under contract for the AEA. The laboratory is expected to come into full operation at the end of the year when facilities for cutting fuel will be completed. In the meantime test samples will be cut from Calder Hall elements at Windscale.

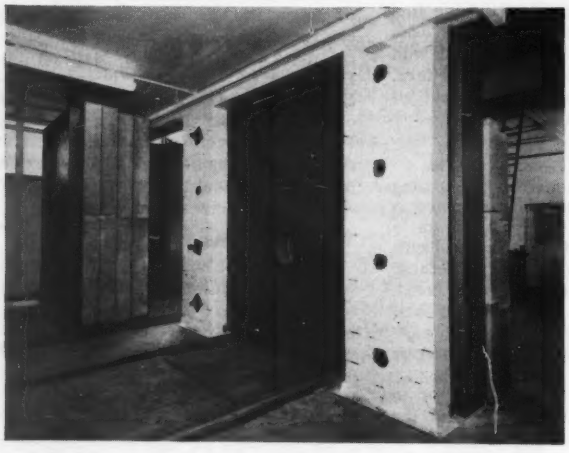
The five interconnected and hermetically sealed glove boxes for the mounting and polishing of small samples prior to examination are already in operation. The cells are mounted in line, on a concrete bench with ports arranged between each cell. Walls are of 6-in. lead slabs with removable concrete roofs. Each cell has an inner container constructed of steel and Perspex. There are lead-glass windows and spherically mounted handling tongs on both sides of each cell.

Movement of the samples through the boxes is as follows. First they are potted in a cold setting resin by an automatic mounting device in the first cell. In the second cell they are polished by three automatic polishing machines. The first rough grinds whilst the second and third polish and lap to a suitable finish. In the third cell the specimens are attack-polished, electro-polished and anodized. The fourth cell forms a temporary storage space. In the fifth there is a variable-load hardness testing machine and a Reichert microscope, modified for remote control.

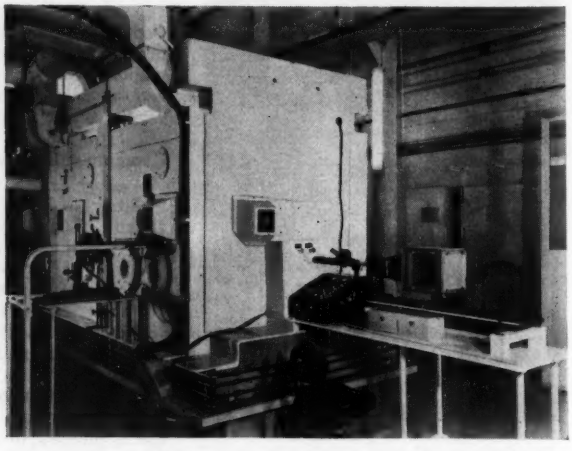
The two large caves are of barytes concrete with 3-ft-thick walls and inner dimensions of 8 ft by 6 ft by 11 ft high. Large doors opening to the full height at the rear weigh 25 tons each. The inside of the doors and the caves is lined with tinned sheet steel and coated with epoxy resin paint. Air is extracted from the caves through filters keeping the air pressure below that of the laboratory which ensures that no air-borne radio-active dust can escape. In addition to lead-glass windows closed-circuit television has been incorporated.

One of the caves is designed for dissecting fuel elements. This is done under water and the machine also removes cladding materials and cuts them up. In the second cave the elements are examined and measured before dissection. Mechanical testing can also be carried out in this cave.

Examinations of irradiated samples planned for the present include certain aspects of the prototype fuel element assembly and sub-components used at the Berkeley power station. In addition components of the fuel element temperature measuring circuit and the control rod system are being studied and an extensive examination of the effects of irradiation on zirconium alloys is being carried out in connection with the support bridges used in reactor fuel element assemblies.



The 25-ton doors to the caves mounted on roller-bearing skates.



Fifth cell and the microscope modified for remote control.

English Electric's Whetstone Works

THE Atomic Power Centre at English Electric's Whetstone Works was officially opened by the Minister of Power, Lord Mills, on July 24, the ceremony being marked by the unveiling of a plaque in the entrance hall. Following the company's normal policy of dissociating development and production, the new laboratories, with a staff of 2,500, have been constructed some 15 miles from the company's main Rugby works. The Atomic Power Division comprises approximately one third of the total effort of the establishment which also includes the central mechanical engineering laboratories and the gas turbine and small steam turbine development groups.

The company's chief interests in the atomic energy field are the Calder type reactor—the English Electric-Babcock and Wilcox-Taylor Woodrow consortium is constructing the Hinkley Point nuclear power station—the advanced gas-cooled reactor and, following a recent liaison with Atomics International of America, the organic moderated reactor, for which a significant future as a ship propulsion unit is foreseen.

Research Facilities

Two analogue computers have been built at Whetstone and a third, SATURN, scheduled for completion in late 1960, is expected to be the most comprehensive analogue machine in Europe. It is designed to permit three dimensional representation of a reactor and will be used to study instability problems which are essentially three dimensional functions.

To permit the complete production of experimental fuel elements and also to do general fabrication research on beryllium a controlled toxic laboratory has been built. This laboratory is provided with full air conditioning and changing rooms and is served by an analysis department capable of doing routine impurity assays of uranium oxide, beryllium, carbon dioxide and neutron poisons as well as providing necessary health monitoring facilities. The equipment provided in the 2,500 sq. ft. fuel fabrication section includes a 1 cwt. vacuum induction furnace, an annealing furnace, an alpha annealing furnace and a beta transfer quench rig. The Stanat Mann precision mill is suitable for both hot and cold rolling and machines for reeling and swaging are also installed. The overall equipment is made up with high temperature salt baths and eight constant temperature furnaces designed for mechanical tests on complete fuel elements.

Adjacent to the fabrication shop is a machine shop with a comprehensive range of machine tools enclosed in Perspex shields and provided with individual ventilation systems. Opposite this is the beryllium laboratory with arc welding equipment, sintering furnace and mechanical test machines for operation at both room and high temperatures.

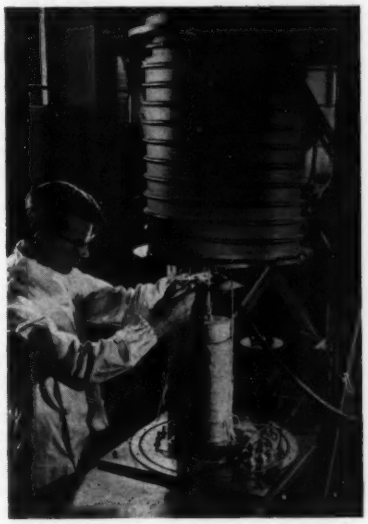
Hot-rolling uranium metal.

Outside the toxic laboratory a great deal of small but essential detailed experimental work is under way. Special facilities include a high temperature friction and wear section, an interface temperature drop measurement room where tests are also being performed on the expanded aluminium thermal insulation which is to be installed in the AGR. Much work is being done on leakage measurement particularly with reference to dry hot CO_2 atmospheres. Items of equipment under test include bearings, valve spindles and electric plugs and sockets.

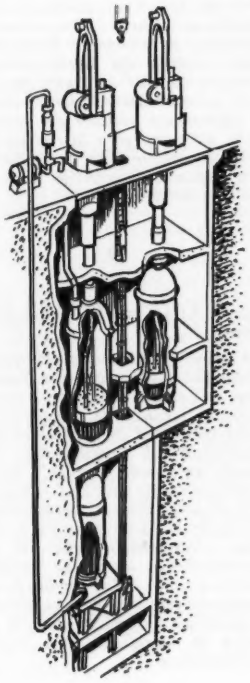
A new facility nearing completion is a charge/discharge gear testing rig. This is being assembled in an 85 ft hole in which a 16 channel section of the graphite core will be contained within a pressure vessel fitted with Hinkley-type stand-pipes and maintained at reactor operational temperature and pressure with the channels carrying the appropriate gas flow. Over this can be brought up the complete charge/discharge gear (minus shielding) and service machine for full scale testing of the system.

Graphite Machining Shop

Also located at Whetstone is the company's graphite machining shop built to handle a total capacity of about 6,000 tons per year. The shop is already in production and will reach full production in 12 months. The blocks for the Hinkley Point reactor are of characteristic pattern and are to be provided with graphite sleeves. The individual blocks received from the AEA are drilled at each end to provide centres, milled to form the correct shapes and the core is then trepanned out. A further trepanning operation produces the sleeve and the rough bore diameter is finally brought to size by a broaching operation. Raw materials supplied have proved to have a slightly lower density than that stipulated (less than 1%) but have consistently shown a better cross section than originally expected.



(Above) Part of the work devoted to the study of heat transfer properties of nuclear materials.



(Left) The pressurized test facility which will operate at over 400°C. and 200 p.s.i.

TRANSLATIONS

Résumés of Principal Articles

Conception et Fabrication de Chaudieres " AGR "

Les températures de gaz plus élevées dans les réacteurs impliquent de nouveaux problèmes en connexion avec la conception et la construction des chaudières, cela sous l'angle des propriétés du matériel de construction, notamment la résistance à la fatigue. Les échangeurs thermiques qui sont décrits et destinés au Réacteur Avancé Refroidi au Gaz de Windscale (Advanced Gas-cooled Reactor "AGR") sont une première expression de la tentative entreprise par International Combustion Ltd. vers la conception d'échangeurs thermiques destinés à réduire la fatigue et permettant un mouvement d'envergure provoqué par la contraction et la dilatation thermiques. La construction envisagée en vue de convenir à une variété de conditions expérimentales n'est pas, par nécessité, du type le plus recherché. D'autre part, aussi bien la construction que la fabrication représentent des méthodes qui demandent des soins particuliers, tels que les conditions de propreté dans les ateliers qui font l'objet d'une description dans le second article.

●

Acier Pour Reacteurs et Installations de Traitement

Des tôles d'acier doux d'une épaisseur de 50,8 mm à 101,6 mm (2 à 4 pouces) sont utilisées pour la construction des récipients à pression destinées aux réacteurs. Deux qualités d'acier convenant à ce but sont prises en considération, à savoir un acier à grain fin calmé à l'aluminium, et un acier à gros grain calmé au silicium. En raison de la tendance à adopter des températures de régime plus élevées, de nouveaux aciers ont été mis au point, du type à faible teneur en chrome et molybdène; il est fait état de leurs caractéristiques de rendement. Il est finalement quastion d'aciers inoxydables austénitiques qui se prêtent comme matériaux pour la construction d'installations utilisées pour le traitement de l'uranium et du plutonium, d'une part, et, d'autre part pour la construction de circuits réfrigérants utilisant du métal liquide. Il est question, pour terminer, de recherches en matière de comportement des aciers sous irradiation.

●

Facilité "ANL" de Fabrication du Plutonium

Une nouvelle facilité a été inaugurée au Laboratoire National de l'Argonne á Lemont; elle est conçue en vue du développement des procédés de manipulation et de fournir, par ailleurs, un appoint limité en ce qui concerne la production d'éléments combustibles. On a construit un système flexible. Le système principal comporte une ligne transporteuse centrale qui dessert un certain nombre de lignes subsidiaires disposées en chevrons. Ont été mises au point des boîtes à gants normalisées dans lesquelles est maintenue une atmosphère d'hélium. Le bâtiment dispose d'installations complètes de ventilation; quant à la décontamination elle est facilitée grâce au fini des surfaces qui a reçu une attention spéciale.

AGR-Kessel, ihre Konstruktion und Ausführung

Höhere Gas-Temperaturen in Reaktoren stellen neue Probleme bei dem Bau der Kessel in Bezug auf Beanspruchungsgrenzen, Eigenschaften der Baustoffe und Konstruktion. Die Wärme-Austauscher, die hier beschrieben werden und für die Fortschrittlichen Gasgekühlten Reaktoren in Windscale (AGR) bestimmt sind, geben das erste Beispiel dafür, in welcher Weise die International Combustion Ltd. die Konstruktion eines Wärme-Austauscher anfasst, um die Beanspruchungen zu reduzieren und grössere Bewegungen des Materials, die durch Wärme-Ausdehnungen und -Schrumpfungen verursacht werden, zu gestatten. Die Konstruktion wurde im Hinblick auf die Einrichtung einer Anzahl experimenteller Möglichkeiten entwickelt und stellt deshalb natürlich nicht einen optimalen Typ dar. Andrerseits erfordern Konstruktion und Fabrikations-Methoden besondere Sorgfalt wie z.b. Sauberkeit in den Werkstätten, wie das im zweiten Aufsatz beschrieben wird.

●

Stahl für Reaktoren und für Anlagen zur Durchführung von Behandlungsverfahren

Für die Hochdruckbehälter von Reaktoren wird Walzstahl in Blechstärken von 2 bis 4 Zoll benutzt. Zwei Stahlsorten werden für den Zweck als geeignet angesehen, ein feinkörniger mit Aluminium reduzierter Stahl und ein grobkörniger mit Silizium reduzierter Stahl. Der Zug zu höheren Betriebstemperaturen hat dazu geführt, dass neue Stahlsorten vom Typ der Stähle mit niedrigem Chrom-Molybdän-Gehalt entwickelt wurden, deren kennzeichnende Eigenschaften gegeben werden. Zum Schluss werden austenitische rostfreie Stähle diskutiert, die als Werkstoff für solche Werke in Frage kommen, in denen die chemische Verarbeitung von Uran und Plutonium vorgenommen wird, und ferner für die Herstellung von Umläufen des als Kühlmittel verwendetem flüssigen Metalls dienen. Es wird schliesslich das Verhalten unter Bestrahlung untersucht.

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Einrichtung einer Plutonium Fabrikation beim ANL

Eine neue Fabrikations-Einrichtung ist im Argonne National Laboratory in Lemont eingeweiht worden, die dazu bestimmt ist, die Entwicklung der Technik des Hantierens von Brennstoff-Elementen zu fördern; die Einrichtungen gestatten ferner eine begrenzte Produktion von solchen Elementen. Die Konstruktion ist als ein wandelbares System ausgeführt worden. Die Hauptanlage besteht aus einer zentralen Fördereinrichtung, die spezialisierte Nebenanlagen bedient, die nach Art eines Fischgrätenmusters angeordnet sind. Ein Standard für Handschuhkästen ist entwickelt worden, in denen eine Helium-Atmosphäre aufrechterhalten wird. Das Gebäude ist mit einer Einrichtung zu umfassender Ventilierung versehen, und besondere Aufmerksamkeit ist der guten Beschaffenheit aller Oberflächen gewidmet worden, um die Entgiftung zu erleichtern.

Diseño y Fabricacion de Calderas AGR

Las mayores temperaturas de gases en los reactores han creado nuevos problemas en la construcción de calderas en términos de resistencia a la fatiga, propiedades de los materiales de construcción y diseño. Los intercambiadores de calor que se describen y que van destinados para el Reactor Avanzado enfriado a gas de Windscale, significan la primera expresión del estudio por la International Combustion Ltd., en el diseño de de intercambiadores de calor destinados a reducir la fatiga y permitir el gran desplazamiento originado por la expansión y contracción térmicas. Su construcción desarrollada con vistas a servir una variedad de condiciones experimentales no es necesariamente de tipo óptimamente mejorado. Por otra parte, los métodos de construcción y fabricación requieren un cuidado especial tal como la limpieza absoluta en los talleres, según se describe en el segundo artículo.

●

Acero Para Reactores e Instalaciones de Tratamiento

Se viene utilizando el acero dulce para recipientes de presión de reactores en espesores de plancha alrededor de 2 a 4 pulgadas (50,8 a 101,6 mm.). Dos tipos de acero adecuados para este fin se tienen en consideración: un acero de grano fino apagado al aluminio y otro acero de grano aspero apagado al silicón. Como resultado de la tendencia a operar a más altas temperaturas se han creado nuevos tipos de acero del tipo de bajo contenido de cromo y molibdeno, cuyas características de performance se ofrecen. Finalmente, se discuten también los aceros inoxidables austeníticos, que son indicados para materiales de construcción de plantas empleadas en el tratamiento químico del uranio y el plutonio, así como para la construcción de circuitos de enfriamiento de metal liquido. Y para terminar, se investiga su comportamiento bajo irradiación.

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Facilidad ANL en la Fabricación de Plutonio

Una nueva facilidad en fabricación ha sido dedicada en el Laboratorio Nacional de Argonne en Lamont, ideada para permitir la evolución de técnicas de manejo y también para dar capacidad de producción limitada de elementos de combustible. Se ha construido un sistema flexible. El sistema principal comprende una línea transportadora central, sirviendo diversas líneas subsidiarias dispuestas en un diseño de espina de arenque. Se han evolucionado cajas de guantes estandardizadas en las que se mantiene una atmósfera de helio. Hay amplias facilidades de ventilación provistas para el edificio, y se está prestando especial atención a los acabados de superficies para facilitar la descontaminación.

Hunterston power station showing the two reactors and the 640-ft turbine hall under construction. The large building in the foreground is the site workshop for fabricating the steam-raising units.

World News

International

EURATOM are to study marine nuclear propulsion systems and the possibility of co-operating with non-member countries in order to avoid duplication of research effort. The Commission has also laid down accounting systems for nuclear materials within member countries.

STEERING COMMITTEE of the OEEC European Nuclear Energy Agency have agreed upon the draft convention on third party liability in nuclear energy and will submit it to the Council for approval and signature.

CIVIL LIABILITY and state responsibility for nuclear hazards has been the subject of study by an IAEA panel; agreement has been reached on the main features of a draft international convention.

IAEA ARE TO SPEND $8.233,000 on research and assistance during 1960. Under an agreement with the U.S. AEC, $20,000 will be financed by the U.S. for research to be conducted by the Agency for the development of cheaper methods for the production of Ca-47 for biological and medical purposes.

SEVENTEEN OEEC COUNTRIES have agreed upon common measures towards safeguarding populations from the dangers of nuclear radiation.

A CTR INFORMATION CENTRE has been proposed by the Scientific Advisory Committee of the IAEA. A journal to cover developments in this field has also been proposed.

JOINT REACTOR BOARD under the U.S.-EURATOM agreement has been formed. The Board will be responsible for the implementation of the programme to construct nearly 1,000 MW of nuclear power plants in the EURATOM countries.

GIFT from the Australian Government to the IAEA comprises complete sets of 10 of the leading scientific and technical journals in Australia plus free subscriptions for them.

United Kingdom

CEGB have been granted permission to erect a 500-550 MW nuclear power station at Dungeness, Kent. It will be the sixth nuclear power station in the U.K. and work on it will be started next year. Tenders will probably be asked for in September or October.

FOUR SCIENTISTS, led by Dr. R. Hurst (Dounreay), recently visited the 5MW fast reactor at the Academy of Science in Moscow. The reactor has been in operation for a year.

PROTONS were accelerated by the 50 MeV proton linear accelerator at the Rutherford High Energy Laboratory on July 12 for the first time.

THIRD READING of the Licensing and Insurance Bill was completed with support from both sides of the House on July 1 and received the Royal Assent on July 9.

ON VISIT to the U.K.. the U.S. nuclear submarine *Skipjack* has on board Cdr. B. E. P. Sambourne, who will command *Dreadnought*, and two Royal Navy chief petty officers.

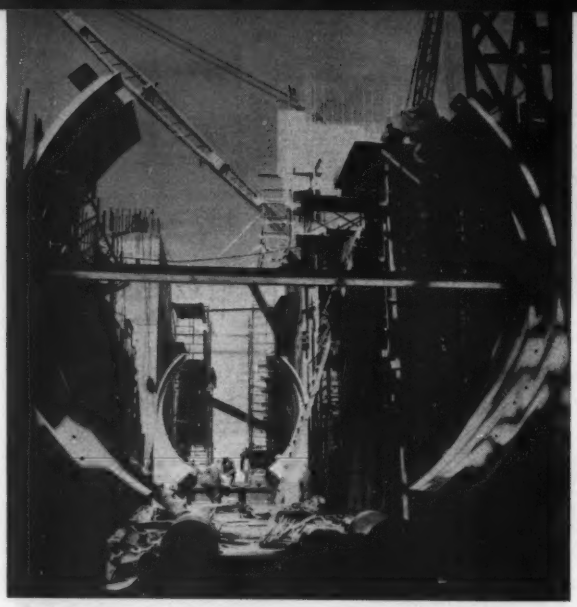
DISCHARGE of radioactive wastes has been examined by a committee of experts in the Ministry of Housing and Local Government. Recommendations call for the existing temporary control of waste from AEA establishments to become permanent while other radioactive discharges will require Ministerial authorization and users of radioactive substances will have to be registered. Necessary legislation is likely to be introduced when Parliament reassembles.

A NEW BRANCH of the AEA has been established with overall responsibility for safety in the Authority's establishments. Dr. A. S. McLean, as Director of Health and Safety, will be in charge.

Austria

CERN has accepted Austria as the 13th European member of the research centre.

SGAE HAVE GRANTED a 99-year lease to the IAEA for a site at Seibersdorf where the Agency intend erecting a functional laboratory. The site is approximately 14 acres.



NPD, the natural uranium heavy-water moderated prototype power station under construction near Rolphton, Canada. The 20 MW power station will feed electricity into the Ontario Hydro power distribution system.

Australia

AN AGREEMENT on the peaceful uses of nuclear energy has been signed with Canada. The agreement is expected to lead to an exchange of information, equipment, facilities and nuclear materials.

URANIUM ORE DEPOSITS near Mount Isa, estimated to hold some £16 million worth of uranium, are to be worked by a new company, Queensland Mines. The company has been especially founded for this purpose.

AN EXPORT LICENCE has been issued to Mary Kathleen Uranium for the sale of uranium oxide to Japan. This follows official permission for the sale of small sample quantities of uranium oxide to countries other than Britain and the U.S. by the Commonwealth Government.

Canada

ATOMIC ENERGY of Canada are to begin the final design and early construction of a 200 MW natural uranium, heavy-water moderated nuclear power station immediately. The plant is expected to cost about $60 million and will be known as CANDU (Canadian Deuterium Uranium).

AGREEMENT for nuclear co-operation and for an exchange of technical information has been signed with Japan.

DELIVERIES of 60 units of an order of 300 uranium oxide fuel elements have been made by AMF Atomics (Canada) to Atomic Energy of Canada. The fuel elements are the first ceramic ones produced in Canada and the total order is worth $175,000.

A REACTOR SCHOOL is to be set up at Chalk River where three-month courses each limited to 20 graduate students will begin early next year.

THIRTY-THREE THERAPY machines were shipped from AECL Commercial Products Division last year bringing the total to 147 spread over 27 countries. Six cobalt-60 models and one caesium-137 are currently available.

China

ORDERS FOR nucleonic equipment worth £17,000 including scintillation counters, scalers and ratemeters, were placed with Ekco Electronics of the U.K. during July.

FOUR CANCER TREATMENT machines, valued at $180,000, have been shipped by Atomic Energy of Canada, Ltd. Total value of radiation therapy shipments received from Canada to date is $300,000.

Denmark

A NEW NUCLEAR INSTITUTE, costing £800,000, is to be constructed at Risø, for use by the Institute of Theoretical Physics.

INSTITUTE for Theoretical Physics have bought a 10 MeV Van de Graaff accelerator from High Voltage Engineering.

France

IT IS REPORTED that G2 at Marcoule has been operated at a heat rating in excess of the design figure of 130 MW. All operational difficulties have, however, not yet been overcome and only a low load factor is possible. G3 diverged on June 8.

Germany

DESIGN for an Argonaut type reactor for Die Kernreaktor Bau und Betriebs Group in Karlsruhe has been awarded to Siemens-Schuckertwerke.

FIRST CONTRACTS for a 16-MW high temperature nuclear reactor to be constructed in West Germany at Jülich in North Rhine-Westphalia have been signed by Krupp and Brown Boveri.

The Czechoslovakian research reactor at the Institute of Nuclear Physics. Work is in progress on the country's first nuclear power station, a 150 MW natural uranium, heavy-water moderated type.

India

FIFTEEN TONS of heavy water for the zero energy research reactor at Trombay are to be leased from the U.S.AEC.

Italy

EURATOM is to set up its first research centre at Ispra, the present site of CNRN'S laboratories; existing facilities will be greatly expanded.

A SUM of £14 million will be lent by the World Bank to the Italian Fund for the South to aid construction of the SENN power station.

NEGOTIATIONS for the purchase of a research and training reactor by the Navy are now under way with American Machine and Foundry. The reactor, to be installed near Leghorn at the Navy's Centre for Military Application of Nuclear Energy, will be of the swimming-pool type, operating with a 3 MW capacity.

New Zealand

A 3 MeV particle accelerator is to be bought from the U.S. for the Institute of Nuclear Sciences.

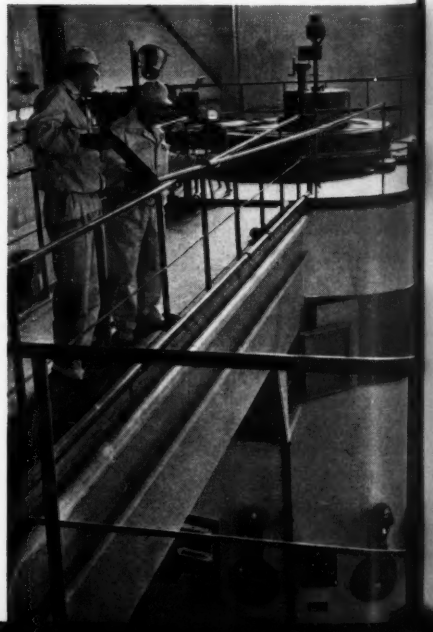
Philippines

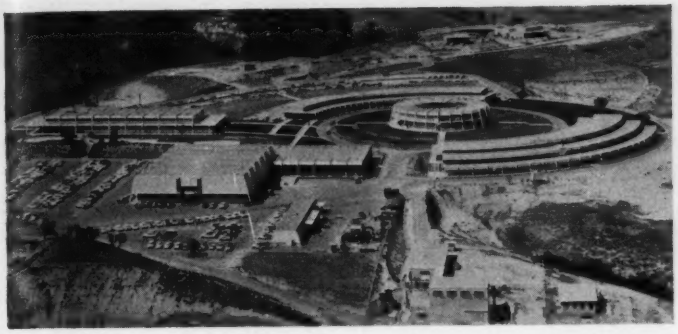
AN ECONOMIC GRANT of $500,000 has been made by the U.S.AEC to the Government for the purchase of a U.S. General Electric open pool research reactor. The 1 to 3 MW reactor will be located at a nuclear research centre, to be built at the University of the Philippines near Manila.

South Africa

A NUCLEAR PHYSICS FACULTY has been instituted at the University of the Witwatersrand with Dr. J. P. F. Sellscop as holder of the chair.

£4 MILLION is to be spent on nuclear research in the next five years and discussions between the Atomic Energy Board, Council for Scientific and Industrial Research and the Minister of Mines, are now taking place to decide the programme.





The John Jay Hopkins Laboratory for Pure and Applied Science built by General Dynamics at San Diego, California. The laboratory, which will house the 700-man staff of General Atomics, was dedicated on June 25.

Spain

A 30 MW REACTOR for power production and testing of fuels will be installed as the second stage of Spain's nuclear programme. Third stage will comprise the building of a 200-250 MW power station on a site near the River Tagus.

Turkey

RESEARCH AND TRAINING, 1 MW pool-type reactor, is to be built for the Turkish Atomic Energy Commission by American Machine and Foundry. It will be situated at the new nuclear research institute to be constructed near Istanbul.

U.S.S.R.

PWR CONSTRUCTION has begun at Novovoronezhskaya, on the River Don. Station capacity will be 210 MW generated by three 70-MW turbogenerators. The reactor will operate at 100 atm and 275°C, the pressure vessel being 12½ ft dia by 70 ft high; fuel charge is estimated at 44 tons.

MINISTER for the construction of power stations, Ignaty Novikov, has stated that a number of commercial power stations of high capacity are to be constructed within the next seven years.

AN AGREEMENT for technical and material assistance in the peaceful uses of nuclear energy is expected to be signed with Iraq. A four-man delegation of the Iraq Atomic Energy Commission is at present visiting Russia.

U.S.A.

ASTRONUCLEAR LABORATORY to develop nuclear energy for outer space applications is to be part of Westinghouse Electric's new nuclear division.

TWO NEW MAJOR scientific divisions, High Energy Physics and Solid State Science, have been formed at the Argonne National Laboratory.

A BOILING SULPHUR cooled reactor proposal has been selected as a basis for contract negotiations by the AEC. Designed by Aerojet General Nucleonics the concept involves the use of boiling sulphur at 1,200°F as a coolant.

TEST IRRADIATION services by Babcock and Wilcox have been selected by the AEC as a basis for contract negotiations. A 60 MW water-cooled and moderated reactor costing $15 million will be used.

RESEARCH AND DEVELOPMENT on sodium heavy-water reactor concepts have been suspended by the AEC after more than two years' study. The Chugach Electric Corporation had intended building a 10-MW reactor of this type at Anchorage.

MONTICELLO URANIUM MILL, owned by the AEC, is to close down on January 1, 1960. The mill, which is the only uranium ore processing plant owned by the AEC, will be maintained in a stand-by condition.

CONTRACTS for the construction of hulls for nine nuclear powered submarines, capable of firing Polaris missiles, have been placed by AEC.

NUCLEAR SUPERHEAT SYSTEM development forms the subject of a contract placed with Combustion Engineering and General Nuclear Engineering awarded by the AEC and worth $4.3 million.

THE SODIUM REACTOR EXPERIMENT (SRE) of Atomics International has produced superheated steam of 1,000°F. Molten sodium, the heat transfer medium, was heated to 1,060°F during the record period.

FUEL REPROCESSING is to be the subject of a two-day conference on October 20-21 in Washington, sponsored by the AEC in co-operation with contractors.

CONTRACTS for three programmes, involving research and development to improve nuclear power reactors, have been awarded to the Advanced Technology Laboratories. The contracts, awarded by the AEC, are expected to total more than $2 million.

AUTHORIZATION for the construction of a two-mile-long particle accelerator at Stanford University is to be sought by the AEC of Congress.

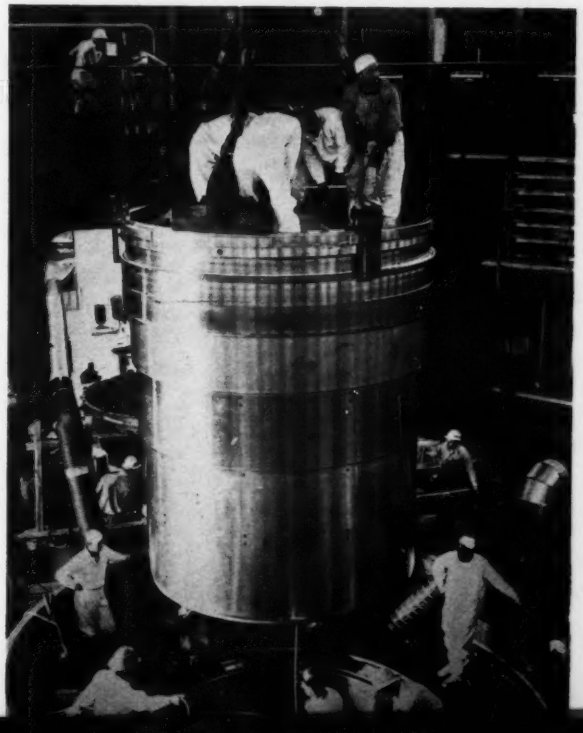
A 50-MW DIRECT-CYCLE, forced-circulation, boiling-water power station is to be built by Consumers Power on Lake Michigan at Big Rock Point.

THE DESIGN of an organic liquid-cooled and moderated reactor to propel a 60,000 deadweight ton tanker has been completed by Atomics International.

CONSTRUCTION of a 12.5-GeV particle accelerator has begun at the Argonne National Laboratory. Called ZGS (zero gradient synchrotron) it will cost about $29 million.

A NEW RADIATION therapy facility for the AEC's medical research installation at Oak Ridge is to be built at the cost of $20,461.

$1.7 MILLION is to be spent on the construction of a high-level radiation facility for the U.S. Naval Research Laboratory. Vitro Engineering will build the laboratory, which is to include studies for the safety of nuclear-powered vessels.



The 106-ton rotating-shield plug for the Enrico Fermi power plant being lowered into place at Lagoona Beach, Michigan. The plug is 9½ ft in diameter and fits into the top 12 ft of the 36-ft-high reactor vessel.

Personal

Sir Roger Makins

Maj-Gen. S. W. Joslin

Sir William Cook

Sir Claude Pelly

Appointments

Sir Roger Makins, at present Joint Permanent Secretary to the Treasury, to be Chairman of the AEA, in succession to Lord Plowden, who relinquishes this post at the end of the year.

Air Chief Marshal Sir Claude Pelly, as member (designate) for weapons of the AEA. Sir Claude has been Controller of Aircraft at the Ministry of Supply since 1956.

Mr. J. B. Adams as director of the new establishment to deal with controlled thermonuclear research. Mr. Adams is at present director of the proton-synchrotron group at CERN.

Mr. J. H. Williams as member of the U.S. AEC to succeed **Mr. W. F. Libby.**

AEA Industrial Group reorganization:

Directors, Development and Engineering Group.

Sir William Cook, member for development and engineering, chairman of the group.

Mr. P. T. Fletcher, departmental manager.

Mr. A. M. Allen, personnel and administration.

Mr. H. V. Disney, engineering.

Dr. R. Hurst, Dounreay.

Dr. H. Kronberger, research and development.

Mr. R. V. Moore, reactor design.

Mr. D. R. Newman, finance.

Mr. T. L. Viney, works and building.

Directors, Production Group.

Sir Leonard Owen, member for production group, chairman.

Mr. J. C. C. Stewart, deputy managing director (operations).

Mr. J. B. W. Cunningham, deputy managing director (technical).

Mr. J. D. Granvill, director, commercial.

Dr. J. N. Hill, director, technical.

Mr. S. S. Hines, general manager, Capenhurst.

Mr. G. R. Howells, general manager, Chapelcross.

Dr. A. B. McIntosh, director of development.

Mr. D. F. Mitchell, director of personnel and administration.

Dr. H. Rogan, general manager, Springfields.

Mr. K. B. Ross, director of operations.

Mr. T. Tuohy, general manager, Windscale and Calder.

Mr. C. J. Turner, director, engineering.

Maj-Gen. S. W. Joslin, chief inspector of nuclear installations.

Dr. J. V. Dunworth, deputy director of Winfrith Heath.

Prof. F. A. Vick, deputy director of AERE, Harwell.

Dr. S. Eklund, chairman of the International Board of Management of *Dragon*; **Sir William Penney,** vice-chairman; **Mr. C. A. Rennie,** chief executive.

Dr. B. G. Dickens, director-general Atomic Weapons.

Mr. R. J. Smith in charge of the General Electric organization in Japan to supervise the building of the 150 MW nuclear power station.

Mr. J. F. MacGillivray as chief staff officer, AEA, Chapelcross.

Mr. C. R. King to be chairman of the Electricity Council in succession to **Sir Henry Self** who retires on August 31. **Prof. R. S. Edwards,** at present part-time deputy chairman of the Council, will serve full time from October 1.

Dr. C. M. Cawley as chief scientist to the Ministry of Power.

Prof. N. Bohr, chairman of the Danish AEC, as director of the new nuclear centre to be constructed at Risø.

Mr. E. Seymour-Semper as president of the Institute of Welding.

Sir George Thomson, president, The Institute of Physics.

Prof. C. F. Powell, scientific policy committee, CERN.

Dr. C. P. Haigh, director of the CEGB Berkeley Nuclear Laboratories.

Mr. A. L. G. Lindley, vice-chairman and managing director, G.E.C.

Dr. D. H. Pringle, chief physicist of Nuclear Enterprises.

Prof. W. B. Hall, professor of nuclear engineering, Manchester University.

Dr. M. Hamermesh, director, physics division, Argonne National Laboratory.

Dr. W. Reyneger and **Dr. J. J. van Rijsinge** as managing directors of Reactor Centrum Nederland.

Professor A. N. Rylov, of the USSR, as deputy director general in charge of training and technical information of the IAEA.

Dr. A. J. A. Roux as director of nuclear research in South Africa.

Dr. K. S. Singwi of India as resident research associate at the Argonne National Laboratory.

Dr. G. Franco as provisional director of the Ispra nuclear centre in Italy.

Mr. G. B. R. Feilden as managing director of a new company, Hawker Siddeley Brush Turbine. He will take up his appointment some time in September.

Mr. L. Bagrit, chairman and chief executive; **Dr. L. L. Ross,** managing director; **Mr. E. O. Herzfeld,** deputy managing director and controller; **Mr. G. C. Fairbanks** and **Cmdr. H. Pasley-Tyler,** assistant managing directors. **Mr. L. C. Upsdell,** a director and secretary of Elliott Brothers (London).

Mr. W. C. Moore as project manager of the maritime gas-cooled reactor project at General Dynamics General Atomic Division.

Dr. J. T. Kendall, general manager marketing and **Dr. J. Powell,** general manager technical, of Texas Instruments.

Mr. R. A. Gentles as director and vice-president in charge of London office of the Aluminium Union.

Viscount Knollys as chairman of English Steel.

Mr. L. C. Southcott as joint managing director of the Superheater Co.

Dr. A. Frankel to the board of Richardsons Westgarth.

Mr. C. E. Wrangham as joint managing director of the Power-Gas Corporation.

Dr. A. C. Monkhouse as president of the Institute of Fuels.

Mr. W. Padley as administrative controller and **Mr. P. Jardine** as group financial controller of Metal Industries.

Mr. O. Gamba as delegate of the Argentine Atomic Energy Commission to the special council for the preparation of the national programme of energy supply.

Mr. R. Yeoman, general manager for the Hodgkinson Group.

Sir Kenneth Hague as part-time member of the Iron and Steel Board.

Mr. L. A. Johnson a director and sales manager of the Detel Products.

Mr. C. R. Wheeler as a director of Associated Electrical Industries.

Mr. R. H. M. Barkham to the board of Eastern Electricity Board.

Sir Basil Tangye as chairman of the council of the Production Engineering Research Association. **Mr. A. L. Stuchbery** and **Mr. G. R. Pryor** become vice-chairmen.

Mr. G. E. Roth of New Zealand as director of the IAEA Division of Isotope.

Mr. L. S. Yoxall to the board of The Foxboro Co., Foxboro, Mass. He is managing director of Foxboro-Yoxall, Surrey.

Mr. R. L. Cogdale as European resident technical representative of Marconi Instruments.

Colonel L. Bullen as managing director of F. Taylor and Sons. **Mr. G. E. Robertson** as manager, sales and contracts of meter, relay and instrument division and **Mr. P. G. Bevis** as manager, sales and contracts, relay department of English Electric.

Mr. R. A. Arrison as vice-president for engineering of Keleket X-ray division of Tracerlab, Mass.

Mr. D. N. Gifford to the board of Birlec-Efco.

Mr. A. C. V. Clarkson succeeds Mr. M. R. Neville as publicity manager of G.E.C.

Mr. R. M. Jones as assistant manager of Lockheed Nuclear Products, Georgia.

Mr. J. W. Haig Ferguson as divisional director and **Mr. F. Duerden** as manager, electronics department of Bruce Peebles.

Mr. F. Mercer as chairman, **Mr. J. F. Tennent** as managing director and **Mr. F. A. Mercer** as a director of the newly formed company, J. F. Tennent.

Mr. I. H. Gordon as assistant sales manager of Cambridge Instruments. **Mr. R. C. Weigel** as president and director of the Society of the Plastics Industry, U.S.A.

Mr. H. W. Davis as chief technical executive and **Mr. I. B. Johnson** as chief designer of Waymouth Gauges and Instruments.

Mr. D. C. Lennon to the board of Societe de Construction d'Appareils pour Gaz a l'Eau et Gaz Industriel.

Mr. W. McLeod as assistant managing director of Saturn Industrial Gases.

Mr. A. J. Peech as deputy chairman of the United Steel Companies.

Mr. G. P. Norton as chairman and **Mr. H. F. Sherborne** as vice-chairman of Yorkshire Copper Works.

Air Chief Marshal Sir Donald Hardman to the board of New Electronic Products.

Mr. J. Busfield to the board of Crofts Engineers (Holdings), Crofts (Engineers) and J. Parkinson and Son. **Mr. M. T. J. Goff** as a director of the latter.

Mr. S. E. Clotworthy to the board of Metal Closures.

Mr. F. V. Vaissiere to the board of Henley Foundries.

Mr. R. G. C. Stephenson as managing director of Commonwealth Industrial Gases (Australia).

Mr. F. McPherson and **Mr. J. K. W. MacVicar** as joint managing directors of Thermotank.

Mr. W. D. Opher as an additional director of Vickers.

Mr. E. E. Rosen as chairman and **Mr. H. V. Slade** as vice-chairman of the Radio Industry Council.

Mr. A. Eyden to the board of Federated Foundries.

Commander Douglas Marshall to the board of Unit Construction.

Mr. A. L. Cramb as sales director of Brush Electrical Engineering.

Mr. L. E. Kent as president of the Institution of Structural Engineers for 1959-1960.

Mr. P. D. Blackmore as manager of equipment customer's works department of British Oxygen Gases.

Mr. J. N. White as deputy director of the Council of Industrial Design.

Mr. J. F. Robertson to the board of High Duty Alloys. **Mr. I. C. Dick,** secretary of the company, to the board as well.

Mr. C. A. B. Baker as president of the Institution of Mining Engineers.

Mr. R. H. Foster as managing director of M. and W. Grazebrook.

Mr. W. A. Stenzel as nuclear sales manager of Tracerlab.

American Nuclear Society executive committee for 1959-60 are: **Mr. W. Jordan, Mr. L. Koch, Mr. J. W. Landis, Mr. M. C. Leverett and Mr. R. Murray.**

Mr. R. H. Burdett as deputy director (mechanical) in the applications branch, research and development department of the C.E.G.B.

Mr. W. T. Burke to the North Eastern Electricity Consultative Council.

Mr. J. N. Gibson, Mr. J. R. McDonald and **Mr. D. M. H. Rooney** as executive directors of British Insulated Callender's Construction.

Dr. H. B. Stewart to the staff of the John Jay Hopkins Laboratory for Pure and Applied Science.

Industrial Notes

A.E.I.-J.T. and N.P.P.C. are concluding negotiations for extensive collaboration in the nuclear energy field. Joint tenders will be submitted for Dungeness and Sizewell.

G.E.C. have concluded a long-term agreement with **M.A.N.** of Augsburg-Nürnberg for the exchange of information on nuclear technology.

English Electric and **North American Aviation** have signed an agreement for providing mutual assistance in the field of organic liquid-cooled reactor systems.

Hawker Siddeley Nuclear Power have received contracts for the design of a glove box and vacuum melting furnaces from the AEA.

Rolls-Royce are to build a factory to fabricate PWR fuel elements for *Dreadnought* at Raynesway, Derby.

Ekco Electronics have flown the reactor control instrumentation to Copenhagen for installation on DR 3 at Risø. The company have also received an order for nine nucleonic gauges from Iraq Petroleum for installation in the 600-mile pipeline from Kirkuk (Iraq) to Tripoli.

Pye have been awarded the first part of a large order for closed circuit television for the Hunterston nuclear power plant.

Boiler gas circulator panels for the Berkeley power station nearing completion at Sunvic's Harlow factory.

Nuclear Equipment is the name of a new company at Watford, formed by Savage and Parsons and General Mills of Minneapolis to specialize in remote-controlled nuclear handling apparatus.

The Dryer and Gas Plant division of **Birlec** have received an order for two dryers to be installed at the nuclear power plant under construction at Latina, Italy.

Allis-Chalmers have bought the **Commercial Nuclear Reactor Engineering Office** of **Nuclear Products,** Washington. They will take over the commercial reactor obligations as well.

W. J. Fraser, chemical engineers of Romford, have been appointed by **Eurochemic** as consulting engineers on treatment, containment and disposal of all radio-active effluents from Eurochemic's new processing plants and laboratories.

Shell-Mex and B.P. will supply all the petroleum products necessary for the building of the Trawsfynydd power station.

Consolidated Beryllium is the name of a company formed by Imperial Smelting and the Beryllium Corporation of Pennsylvania. It will be managed by Imperial Smelting and will be located at Avonmouth.

The National Institute for Research in Nuclear Science have announced contracts worth £430,000 for the manufacture of magnet coils required for the 7,000-ton electromagnet of the 7 GeV proton synchrotron, NIMROD, being constructed at the Rutherford High Energy Laboratory. They are: **British Copper Refiners** for 300 tons of refined copper; **James Booth** for extrusion of the cast copper into hollow rectangular bars; **Metropolitan Vickers Electrical** for the manufacture of the finished coils from the extruded bars. **Marston Excelsior** have been awarded a contract for the development and supply of the reinforced plastic vacuum chamber in which the protons are accelerated.

General Dynamics of Connecticut have been awarded a contract to provide design, material and technical assistance for the installation of the propulsion system for *Dreadnought*.

Pirelli-General Cable Works have been awarded a contract by The South of Scotland Electricity Board for the manufacture and installation of 19,500 yd of 132 kV single-core oil-fired cable for Hunterston.

Pye Telecommunications have been awarded a £21,000 contract by the AEA for installation of radio equipment for the radio telephone systems at Chapelcross, Capenhurst, Dounreay, Springfields, Windscale, Harwell, Winfrith Heath and Aldermaston.

A physics laboratory and new workshop have been completed at the **Fulmer Research Institute.** Research for governmental bodies since January, 1958, represents 67% of a total of £150,000; 15% represents overseas industry and 18% home industry.

The **Ninth Electrical Engineers Exhibition** will be held at Earls Court from April 5 to 9, 1960.

Tracerlab offer a new semi-automatic liquid scintillation counter, the LSC-10.

Mahomed Ebrahim of Karachi have advised the U.K. trade commissioner that they wish to obtain agencies for nucleonic equipment including counting and recording equipment, radiation analysis equipment, remote handling and monitoring equipment.

Mullards Instruments now offer the TF 1330, a new high-grade, general purpose oscilloscope for detailed viewing and precision measurement of waveforms.

Hopkinsons supplied a comprehensive range of valves to the Chapelcross power station. These included parallel-slide, automatic exhaust, deadweight relief valves and electric controls, desuperheating equipment, centrifugal separators and various kinds of small valves.

Clarke, Chapman and Co. have supplied 48 glandless motor pumps for the high and low-pressure secondary heat-exchange systems at the Bradwell power station.

Ekco Electronics have launched a commercial radiation monitoring and tracer service to cater for the growing use of radio-active isotopes.

Baldwin Industrial Controls is the new name of Baldwin Instrument Company, manufacturers of nucleonic thickness and control gauges.

Plessey Nucleonics have opened a new extension to their Northampton factory.

I.C.I. Metals Division offer four new materials in their range of wrought titanium and titanium alloys. These comprise two additional grades of commercially pure titanium, I.C.I. titanium 125 and 150 and two alloys, I.C.I. titanium 230 and 679. They have also announced price reductions in wrought titanium.

Three orders worth £40,000 for heavy-duty power-operated manipulators have been received by **G.E.C.** from Sweden, Japan and Harwell. The machines will be used for remote handling of irradiated nuclear-reactor fuel elements.

British Indicators (Sales) have been appointed sole agents in the U.K. for the sale of **Burton** hardness testing machines manufactured by J. O. Deakin.

ILMAC, the international exhibition of laboratory measurement and automatic control in chemistry, will take place in Basle, Switzerland, from November 10 to 15.

Evershed and Vignoles' new Scottish address is, 30 Rutland Square, Edinburgh, 1.

Square D have opened a Bristol office at 46 Queen Square, Bristol, 1. Phone, Bristol 20995.

Quasi-Arc automatic welding equipment was used in the manufacture of the 200-ton-capacity Goliath crane at the Bradwell power station. **Clyde Crane and Booth** are building the crane.

Micro Methods are now supplying AEA reports in microform. The reports are available in three groups.

The National Engineering Laboratory are to establish a Creep Information Centre.

The Power-Gas Group has now completed half of its 20-year extension programme. New buildings include a 160,000-sq-ft machine shop and a constructional shop with an area of 200,000 sq ft. Total expenditure to date is £3 million.

Taylor Woodrow are now installing the two-mile submarine section of the twin radioactive effluent pipe-line at Winfrith Heath. They have also completed the two-million-gallon reservoir which will provide the Hinkley Point power station with water.

The eighth annual **SIMA** convention will be held at the Metropole Hotel, Brighton, from October 22 to 24.

Annual meeting of the **British Association for the Advancement of Science** will be held in York from September 2-9. A lecture on the peaceful uses of atomic energy will be given by Mr. P. Potter.

Torvac, Ltd., is the name of a new company located at Cambridge to advise on design and manufacture of all types of special vacuum equipment.

Richardsons Westgarth are to have a four-storey extension costing £100,000 to their head office at Princes Street, Hartlepool, Durham.

Catalogues

The first issue of the *Bulletin* of the IAEA has been published. Articles of special interest are legal protection against nuclear damage, distribution of fission products in the biosphere and the reactor construction programme in Japan. The *Bulletin* will be published quarterly. (Kaerntnerring, Vienna, 1.)

A section on the **Simon-Carves** part in the Hunterston nuclear power plant construction is included in the 1958 report of directors. (Bird Hall Lane, Cheadle Heath, Stockport.)

Atomic Industrial Forum have published a 1959 Atomic Industry Directory of Products. Products, equipment and services are included under 40 major classifications. (3 East 54th Street, New York 22, N.Y.)

A survey on organic coolants and moderators for nuclear reactors has been published by **Monsanto Chemicals.** It is divided into two parts, the first a collection of abstracts from papers on the subject and the second a comprehensive bibliography of papers published on the subject up to early 1958. (10 Victoria Street, London, S.W.1.)

A new brochure on the **Imperial Chemical Industries** production range of zirconium has been produced. (P.O. Box 216, Birmingham.)

The **Cape Asbestos** magazine, volume 8, No. 2, has a pictorial coverage of the company's progress on the insulation work of the Berkeley nuclear power plant. (114 Park Street, London, W.1.)

Articles on ratemeters and detectors are included in the new edition of the **Tracer-matic** nuclear instrumentation section of **Tracerlab's** condensed catalogue F. (1601 Trapelo Road, Waltham 54, Mass.)

M. and C. Nuclear have published a new data sheet on uranium and thorium foil. (P.O. Box 898, Attleboro, Mass.)

A new brochure, NCB-1, on fuel element manufacture describing **Babcock and Wilcox** methods is now available. (20 van Buren Avenue, South Barberton, Ohio.)

Cambridge Instruments describe their electronic recorder in a new publication, **List 186.** (13 Grosvenor Place, London, S.W.1.)

A review of the services of the **Lead Development Association** in 1958 has been published. (18 Adam Street, London, W.C.2.)

Kent electronic amplifiers and level recorder spare-parts are described on leaflets 1009 and 355A. (Luton, Bedfordshire.)

A booklet, *Radioactive markers in go-devils: safety precautions*, has been published by H.M.S.O.

Technical Information announce that a new publication, *Russian Patents Gazette*, is now available. (Chancery Lane, London, W.C.2.)

Swimming pool reactors for research and training, manufactured by **Babcock and Wilcox,** are described in a new booklet. (Atomic Energy Division, 161 East 42nd Street, New York 17.)

Forms and sizes of general plate reactor metals are described in a brochure by **Metals and Controls.** (Attleboro, Mass.)

The 1958 annual report of the **Rio Tinto Company** is now available. (59 Gresham Street, London, E.C.2.)

Lancashire Dynamo Holdings have published their 1958 report. (St. Stephens House, London, S.W.1.)

An attractive, illustrated booklet, the annual review for 1958 of **Solartron,** has been published. (Thames Ditton, Surrey.)

A description of the **Ruston-Grayloc** high-temperature pressure pipe connections is now available. (P.O. Box 2, Lincoln.)

Morgan Crucible have produced new brochures on their oil-fired basin tilting furnace type BT Mk. 2, their electric die-casting furnace and unit type seals. (Battersea Church Road, London, S.W.11.)

International Transistor Exhibition

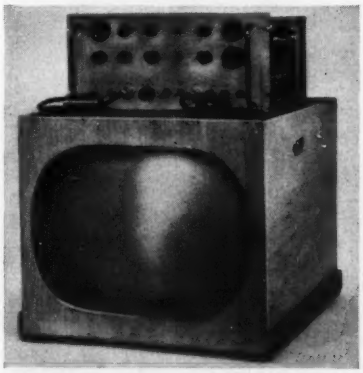
Promoted by the Institution of Electrical Engineers, the Exhibition and Convention proved to be one of the most successful yet held.

Switching transistors by Newmarket Transistor.

THE International Transistor Convention and Exhibition, held in London marks another step in the application of semiconductors. Since the invention of the transistor in 1948, this new technology has developed at a rapid rate. More than 30 papers were presented during the 12 general sessions, and the exhibition housed a surprising variety of interesting equipment making use of transistors.

The Exhibition, held at Earls Court from May 21-27, was promoted by the Institution of Electrical Engineers. Of the 85 exhibitors, 14 were foreign, seven different countries being represented.

The wide application of semiconductors extends to the nuclear industry. An obvious indication of this was the **Atomic Energy Research Establishment** stand, where, on display, was a sensitive transistor oscilloscope with d.c. to 300 Mc/s response. The unit operates on the sampling process where the repetitive waveform is sampled for a very short interval of time, once for each repetition. By slowly changing the instant of sampling in relation to the waveform, the whole waveform can be examined progressively. Display of the amplitudes of the samples obtained is on a cathode-ray oscillograph as a series of dots, which build up a picture of the waveform. The time resolution of this system is determined solely by the duration of the gating pulse which controls the sampling action. One advantage of this sampling process is that the input waveform may be processed at a slow rate in low bandwidth circuits after sampling.



300 Mc/s sampling oscilloscope attachment with 21 in. display unit—AERE.

The oscilloscope probe is arranged to contain all the high speed circuits, viz., gate pulse generator and sampling circuit, and is connected to the main instrument containing the low frequency circuits by a length of multiway cable.

Also shown was a random pulse attachment for the sampling oscilloscope and a logarithmic ratemeter for measuring the radiation levels near a reactor. This instrument displays the level of radioactivity on a logarithmic scale of 0.5 to 500 counts/sec.

Burndept featured a portable thickness gauge employing beta backscatter techniques. This transistorized unit consists of a probe containing the detector connected by a cable to a small case which contains the controls and a 2½ in. moving coil meter. Two 1.5V batteries supply power.

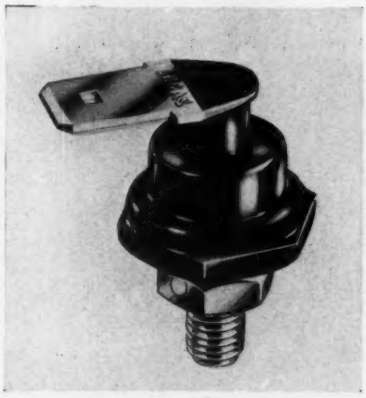
In their range of measuring instruments, **Dawe Instruments** included a fully transistorized audio oscillator covering a frequency range 20 c/s to 20 kc/s and a self-contained battery operated transistor oscilloscope.

An example of the application of transistors to computers could be seen on the **Elliott Automation** stand where the new 802 digital computer was shown.

The **Edwards High Vacuum** stand, while directly related to transistor manufacture, was interesting to nuclear engineers, because the company displayed a series of rotary and diffusion pumps for creating vacuums. The **Birlec** stand was of similar interest because it contained models of a nitrogen generator and a dehumidified room. Birlec's newly designed laboratory dryer will produce extreme dryness down to dewpoints below −55°. This company also showed a dryer working in conjunction with a glove box, producing controlled relative humidities between ¼% and 5% R.H. at ambient temperatures.

A self-contained unit intended for washing semi-conductors and called the Elgastat Robot, was introduced on the **Elga Products** stand. The unit provides conductivity water at 50 gallons per hour; it has been designed to fit into the washing stage for line production of electronic devices.

Texas Instruments stand gave a good indication of the direct application of transistors in typical circuit applications. These included voltage stabilisers and power packs, motor control gear and automatic voltage regulators.



Style D of the Lucas range of high power silicon rectifiers with current ratings of 35—100 amp.

Processes and Equipment

For further information on any item please enter the relevant number on the Reader Service Card enclosed with this issue and forward the card to the address given.

Versatile Jason

With Hawker Siddeley's first Jason reactor rapidly nearing completion at Langley, near Slough, the company have recently sent us details of the many forms in which the reactor can be supplied. Because the core components and the internal and external reflectors are identical in all cases a purchaser can subsequently modify the reactor for a different application.

First, then, Jason can have a rating of 1 to 100 watts, with five irradiation ports in the central thermal column and external beam holes to customer's requirements. In this form the reactor is suitable for exponential experiments, oscillator experiments, the production of short-lived isotopes and activation analysis. Maximum thermal flux is between 1.5×10^7 to 1.5×10^9 depending on the reactor power.

Second, the reactor power range can be stepped up to between 1 and 10 kW, with internal and external thermal columns and two beam holes giving a total of 21 irradiation ports.

Third, in its standard form, Jason can be used for a variety of experimental purposes. With internal and external thermal column and a shield tank the unit is rated at 10 kW continuous.

Fourth, in the 10 kW (continuous) form, with one internal and two external thermal columns, Jason can power two exponential experiments or, alternatively, form part of an irradiation scheme.

Finally, and still with the power level at 10 kW, the reactor can have a 10-in. beam hole for neutron therapy studies. At full power average thermal flux across the beam hole is 8×10^6 n/cm², sec. Such a reactor would normally have one internal and one or two external thermal columns.

A zone of higher flux can be incorporated by installing a central heavy-water irradiation space. This increases the available thermal flux at any given power by a factor of 1.5 to 2. The Jason can also be operated for limited periods at powers higher than the continuous rating.

(Hawker Siddeley Nuclear Power Co., Ltd., Sutton Lane, Langley, near Slough, Bucks.)

1210

Simplified Scintillation Technique

The NE 8301 system developed by Nuclear Enterprises of Edinburgh affords an efficient but greatly simplified scintillation technique for the measurement of carbon-14 and tritium radioisotopes.

Outstanding features of the 8301 system are the use of a 1-in. diameter E.M.I. photomultiplier tube, selected for low noise level; the new NE 5503 shielded scintillation head, incorporating a rotary light locking device which permits operation in daylight without exposure of the photomultiplier to light; silver silica counting cells; the NE 5202 Fairstein non-overloading linear pulse amplifier with high gain (5 by 10^4), allowing operation of the multiplier at a low voltage and improving signal to noise ratio; pulse height selector NE 5102, which optimizes signal to background ratio and NE 5302, an E.H.T. source with an overall stability of 0.01% per 24-hour period with re-set accuracy to 0.1V.

Adequate temperature stabilization is achieved by water-cooling the photomultiplier whilst the use of an NE 213 liquid scintillator adjusted to produce a minimum quenching effect on the additions of samples ensures efficient measurement of the isotopes.

Counting of two or more isotopes simultaneously can be effected with two pulse height selectors each set to count a particular isotope in the most appropriate fashion. Successful routine analysis of such binary and ternary mixtures as $H^3 - C^{14}$, $H^3 - Na^{22}$, and $H^3 - C^{14} - P^{32}$ can be made. The NE 8301 assembly may also be applied to systems in which an insoluble sample is dispersed in a finely divided state throughout the scintillator. The Steinberg technique—where small plastic phosphor spheres are used as the scintillation medium while the liquid to be investigated fills up the intervening spaces—can also be utilized with the NE 8301 system.

(Nuclear Enterprises (G.B.), Ltd., Bankhead Medway, Sighthill, Edinbu gh, 11.)

1211

Electronic Flowmeters

Rochar electronic flowmeters are now marketed in the U.K. by Metrix Instruments. These units are extensively used in power stations for the measurement of instantaneous rate and integrated volume of the flow of liquids.

The volumetric transducers are of the magnetic induction type; they comprise a

(Left) NE 8301 assembly for carbon-14 or tritium counting by Nuclear Enterprises of Edinburgh.

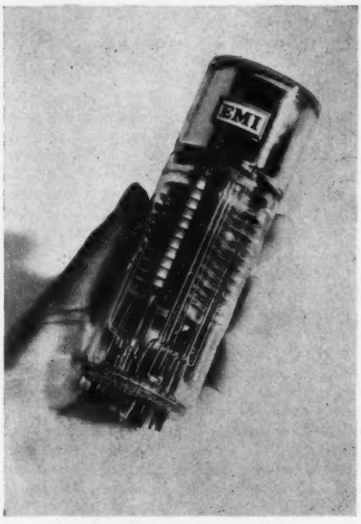
(Right) Metrix Instruments are now marketing Rochar electronic flowmeters in Great Britain.

cylindrical body, through which the liquid passes, and a free rotor with helicoidal blades, the speed of rotation being proportional to the flow rate. The a.c. signal output from the transducer has a frequency in cycles per second equal to the revolutions per second of the rotor.

The measuring instrument consists of a frequency meter with a pulse-shaping circuit and an output meter calibrated in terms of instantaneous rate of flow. An auxiliary circuit provides an output pulse for every complete unit of volume which is fed into a mechanical counter to indicate the total volume of flow at any time. The range of flow rate is from 20 to 100,000 litres/hour. Calibration can be effected in any units.

(Metrix Instruments, Ltd., 54 Victoria Road, Surbiton, Surrey.)

1212



Type 9558B photomultiplier tube by E.M.I. Electronics.

New Photomultiplier

E.M.I. Electronics latest photomultiplier tube, type 9558B, has a tri-alkali photocathode formed from antimony sodium potassium caesium. The cathode is characterized by a high quantum efficiency of between 15% and 20% in the blue region (at 4,200 Å) and an extended red response of up to 8,500 Å, while having at the same time a very low value of dark current. A typical tube has a photo sensitivity of 100 μA/L, an overall sensitivity of 200 A/L at an average of 1,700 volts and a dark current under this condition of 0.003μA. E.M.I. say that these tubes are especially suitable for spectrometry, particularly flame spectrometry, and for scintillation counting with materials such as caesium iodide and also for scintillation counting of C^{14} and H^3.

(E.M.I. Electronics, Ltd., Hayes, Middx.)

1213

Protective Clothing

Pressure ventilated clothing developed in collaboration with U.K. AEA safety officers is now being marketed by Plysu Products of Bletchley, Bucks. According to a brochure which the company has recently published, Plysu clothing offers complete freedom of movement and, because of its light weight, is particularly comfortable to wear.

Swiftplan's new 311 series of buildings are designed for ease of transportation and rapid site erection.

The entire range of Plysu pressure ventilated suits is made of PVC and all seams are high frequency welded. The hoods can be worn with the air inlet at the back or front and air diffusers prevent discomfort to the wearer who can adjust his own air flow by means of a belt mounted control valve.

(Plysu Products Ltd., Woburn Sands, Bletchley, Bucks.)

1214

Interval Timer

Although General Radiological's NE.068 interval timer was originally developed for the control of NE.075 slow scalers, the unit can control any process initiated by either a short exponential pulse or the periodic operation of a change-over contact.

Pulses from a hermetically sealed electromechanical timer are fed at four per second to a scale of four to provide output pulses at one per second. The timing unit starts automatically when the equipment is switched on. The impulses operate an electromechanical counter which subtracts one digit per impulse from the pre-set time indicator. When the predetermined time interval has elapsed the change-over contacts are operated and the unit remains in the ready state. An adding counter can be fitted to provide an indication of elapsed time.

(General Radiological, Ltd., 18 New Cavendish Street, London, W.1.)

1215

Mobile Buildings

Contractors on nuclear power station sites in this country are already aware of the need for transportable buildings to serve as site offices, dormitories or ablutions. Recently one building manufacturer, Swiftplan, erected fully-equipped sleeping quarters for over 100 men at Hinkley Point within a week of the buildings being dispatched from London by road.

Swiftplan's new 311 series of buildings are particularly attractive and easy to erect. Based on a stressed skin system of construction, each building can be fitted with floor covering, decorations, plumbing, electrical installations and central heating in the factory where the units are assembled. The building is then delivered to the site by lorry in packs measuring 25 ft by 8 ft by 2 ft., four of which can be carried on a single vehicle. Off-loading and erection on prepared footings by crane takes only a matter of minutes, and when necessary the complete building can be folded up and moved to another site.

(Swiftplan, Ltd., 39 Victoria Street, London, S.W.1.)

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Isotope Coffins

Westover isotope coffins are designed in a range of six sizes, the largest of which will cut the dose-rate from a 10,000 c cobalt source to 3 mr/h at 1 m. The cartridge size can be up to 1 in. (25 mm) diameter with an overall length of 8 in. (203 mm). Other cartridge sizes can be incorporated by modifying the container.

The cylindrical coffin has a 1-in.-diameter stainless-steel tube through the centre, the ends of the tube being spun back into the end plates and machined flush. Surrounding the s.s. tube there is a lead annulus 1 in. thick which is contained in another steel tube. The bulk of the lead is poured around the latter tube, the density being 707 lb/cu ft.

Carrier trucks, with steel wheels for rail mounting or free-running rubber-bonded steel wheels, can be supplied for carrying the coffins. The company is also able to offer a range of spherical coffins which are shorter in length.

(Westover Nuclear Equipment Co., Ltd., Riverside Works, River Road, Barking, Essex.)

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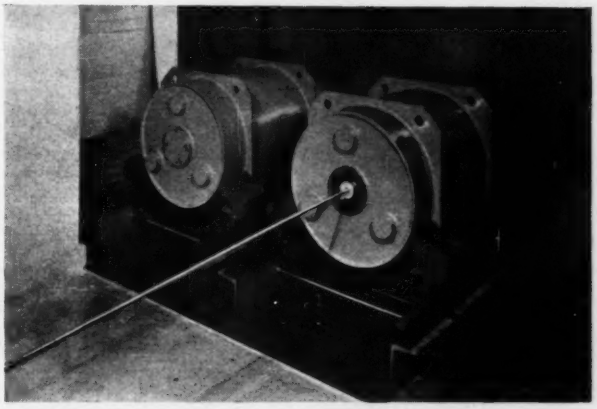

(Right) Cylindrical isotope coffins by Westover can be used for storing antimony 124, sodium 22, sodium 24, cobalt 60, radium and tantalum.

Patents Reviewed

These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).

B.P. 803,990. Anodic treatment of uranium metal. R. A. U. Huddle, O. Flint and U.K. Atomic Energy Authority.

A method is proposed for the cleaning of tarnished surfaces of uranium components, such as rods, for instance, by anodic treatment resulting in a bright surface which is retained, on exposure to air, for periods of up to 12 months. The rods are made anodic in concentrated sulphuric acid (1.84 s.g.), to which 5% by weight of chromium trioxide may be added. The cathode should be of lead and separated from the anolyte by a porous diaphragm. A potential of 12 V should be applied. In the course of the treatment the initial current decreases, apparently due to the formation of a thin oxide film which imparts a passive condition to the surface.

B.P. 804,064. Improved method for the production of uranium. W. H. Cooke, J. W. C. Crawford and U.K. Atomic Energy Authority.

The manufacture of easily oxidizable metals such as uranium has to be carried out in an atmosphere excluding air. The atmosphere may consist of hydrogen and serve directly as reducing agent or, alternatively, a blanket of noble gas, argon, may be used. In the case of hydrogen it was found that substantial absorption by the metal occurs during the process leading to an impure product. On the other hand, rare gases such as argon are expensive. In order to improve the economy of manufacture it is proposed to produce metallic uranium by the reduction of a uranium compound with a more electro-positive metal carrying out the reduction in a reducing atmosphere and subsequently, i.e., during the period when the melt cools, to maintain an atmosphere of argon. A suitable method of production is reacting uranium tetrachloride or the double salt of uranium tetrachloride and sodium chloride with an alkali metal such as sodium or an alkaline earth metal such as calcium or magnesium, or with aluminium.

B.P. 804,395. Improvements to nuclear reactors. H. C. Knights, H. Morris and U.K. Atomic Energy Authority.

The temperature of the sheath material enclosing the nuclear fuel requires careful observation during reactor operation. In order to measure the temperature of the sheath accurately thereby facilitating running at as high a temperature as possible with safety, a small thermocouple is placed in a suitable position on the surface of the sheath of the fuel element. The present invention is essentially concerned with a cable arrangement connecting the thermocouple on the element with a recording apparatus and is designed to form an integral part of a suitably constructed lifting arrangement for the individual fuel element.

B.P. 804,621. Electromagnetic pumps. P. Fortescue and U.K. Atomic Energy Authority.

A liquid metal duct is arranged axially within the poles of a three-pole circular iron yoke structure. A magnetic field is created transversely across parts of the duct section in turn by field coils on the yoke (with secondary windings and electrodes around the duct) excited by three-phase current and thus a longitudinal pumping action is effected on the liquid metal in the duct.

B.P. 804,787. Process for effecting a self-sustaining nuclear fission reaction by means of neutrons. Stichting Reactor Centrum Nederland (Netherlands).

Refers to the processing of fuels in a circulating liquid suspension. Fission products are removed from the fuel suspension by adding solid particles of low neutron-absorption capacity, which in the suspension will adsorb fission products liberated into the carrier liquid. These solid particles are added in such quantities that they have collectively an adsorption capacity considerably greater than that of the fissile particles in the suspension. The particles are continuously or periodically separated from the suspension and the removed particles replaced by further adsorbing particles. Owing to the high specific gravity of the fissile material (uranium oxide; thorium oxide) separation is conveniently effected by conducting at least part of the circulating suspension through a secondary circuit and a hydrocyclone which separates the suspension into two fractions. The fission products are separated in a filter and the carrier liquid free from solid matter returned to the suspension circuit. Carbon particles are preferred for adsorbing the fission products.

B.P. 804,962. Preparation of high purity lithium carbonate from crude aqueous lithium chloride. G. L. Canningham and Chempatents Inc.

An aqueous solution containing from 15 to 30% lithium chloride together with a concentration of sodium chloride or potassium chloride, or both, is treated with sodium carbonate and heated to 95 to 100°C. Solid lithium carbonate is then separated from the heated mixture.

B.P. 804,999. Method of separating plutonium. U.K. Atomic Energy Authority. (U.S.A.)

A vaporous mixture of the hexafluorides of uranium and plutonium is passed over a heated copper surface (100 to 455°C). Plutonium is removed through deposition on the copper.

B.P. 805,001. Method of separating uranium. U.K. Atomic Energy Authority. (Canada.)

The irradiated uranium metal is dissolved in concentrated nitric acid. The acidity is closely controlled and must not be above stoichiometric neutral in order to avoid extraction of plutonium together with the uranium. A salting out agent such as ammonium nitrate is then added to the solution and extraction is obtained by treating this solution with an organic solvent, preferably ethyl ether, which is sufficiently water-immiscible to form a separate phase and permit extraction of the uranyl nitrate without extracting the plutonium or other fission products at the same time. Details are given of a typical application resulting in 96.9% extraction of the uranyl nitrate with only 1.3% of plutonium and 0.09% of the fission products present in the original solution.

B.P. 805,302. Separation of plutonium. U.K. Atomic Energy Authority. (Canada.)

The use of triglycoldichloride has been proposed as the non-aqueous solvent for a fractioning method in which the plutonium is extracted from aqueous nitrate solutions into a non-aqueous phase to uranium and/or fission products, which remain in the aqueous phase. It has been found that triglycoldichloride is much more effective when it has added to it a saturated aliphatic-aldehyde containing at least two carbon atoms per molecule, benzaldehyde, or a polyhydric phenol.

B.P. 805,361. Treatment of aqueous fission product solutions. T. W. Boyer, J. G. MacHutchin and L. Yaffe.

Solutions of the kind described in B.P. 805,001, after solvent treatment in order to extract the uranyl nitrate and the plutonium, exhibit considerable radioactivity due to the presence of fission products. As these solutions usually comprise considerable volumes, the storage problem is serious. Therefore, it is proposed to treat the solution with a carboxylic acid anydride, such as acetic anydride, to react with and destroy the ammonium nitrate. Subsequently, the solution can be concentrated by evaporating the liquid resulting in the fission products remaining in a small volume of acetic anydride-acetic acid mixture.

B.P. 805,501. Production of niobium and tantalum compounds. R. W. Blundell and U.K. Atomic Energy Authority.

Niobium sources (ores and crude commercial products) usually contain tantalum and chemical extraction processes therefore yield niobium with an appreciable tantalum content. Extracting niobium and tantalum by heating with potassium hydroxide and then separating potassium niobate and potassium tantalate from insoluble matter results in considerably less niobium and tantalum than are present in the source material. It has been found that the losses occur through the presence of iron in the source and these losses can be reduced if the formation of ferric hydroxide is avoided by performing the heating step under reducing conditions (in the presence of metallic iron) and if subsequently precautions are taken to avoid such formation while the hot alkaline potassium niobate and tantalate solution is in contact with the insoluble matter.

B.P. 805,752. Concrete or like constructional materials affording protection against nuclear radiations. J. H. Fischel and L. Martin. (France.)

A material suitable for use in the construction of protective buildings is described. A natural or artificial barium compound to afford protection against alpha-, beta- and gamma-rays and graphite to afford protection against neutrons is used in admixture with a hydraulic binding material. The most convenient and inexpensive barium compound is the natural form known as barytes or heavy spa. The proportion of the barium compound and graphite should be 60-86%, and of the cement 40-14% (by weight).

B.P. 805,782. Uranium alloys useful for the release of atomic energy. U.K. Atomic Energy Authority. (Canada.)

A binary uranium-silicon alloy containing 0.5 to 10% (preferably between 1 and 8%) of silicon. Silicon reduces the tendency of uranium to corrode at high temperature and has a small neutron capture cross section.